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MEMOIRS VAN DIE BOTANIESE OPNAME VAN SUID-AFRIKA

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A PHYTOSOCIOLOGICAL STUDY OF THE UPPER ORANGE RIVER VALLEY

M.J.A. WERGER

BOTANICAL RESEARCH INSTITUTE • DEPARTMENT OF AGRICULTURE AND FISHERIES • REPUBLIC OF SOUTH AFRICA
NAVORSINGSINSTITUUT VIR PLANTKUNDE • DEPARTEMENT VAN LANDBOU EN VISSERYE • REPUBLIEK VAN SUID-AFRIKA

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A PHYTOSOCIOLOGICAL STUDY

OF THE

UPPER ORANGE RIVER VALLEY

WITH 68 FIGURES (INCLUDING THREE VEGETATION MAPS) AND 19 TABLES

by

M.J.A. WERGER

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1980

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BOTANICAL RESEARCH INSTITUTE
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Foreword

The availability of water constitutes one of the major limiting factors to the economy and agriculture of South Africa. The urgency of the study of catchments, which constitute the primary source of our water, is therefore obvious. In this respect vegetation surveys are of primary importance, since the plant-cover of catchments and river valleys will, to a large extent, determine the constancy of supply, the quality of the water as well as the amount of siltation of dams and weirs that will take place.

As early as 1950 Killick started the first catchment survey at Cathedral Peak in Natal. The work was undertaken by this Institute on behalf of the Department of Forestry with the main aim of collecting information for management purposes. In a broad sense Edwards's study of the Tugela River Basin in Natal is also a catchment survey. Werger's contribution is thus the third in this field to be undertaken by the Institute.

Several factors make his study of special significance. It is the first major survey based on the Braun-Blanquet or continental Zürich-Montpellier method in the Republic and the first providing a lengthy transect of vegetation from east to west, traversing the high Drakensberg foothills, the Highveld grasslands and the Upper Karoo. In addition, it includes areas now flooded by the Hendrik Verwoerd Dam.

As the first of the new series of surveys based on the Zürich-Montpellier method of survey, its historical background deserves some comment. Ecologically the sixties were characterized by a questing for an efficient and scientifically-sound method of ecological survey. Many methods had been tried, including descriptive, subjectively-orientated methods and association-analysis aided by computer techniques. None of these methods proved wholly acceptable, even though good results were achieved with most of them. After a visit to France, Germany, Switzerland and the Netherlands in 1964, Edwards proposed that the Zürich-Montpellier approach should be tried out as a possible standard method for future surveys. This resulted in the recruiting of Dr Werger who had received a thorough grounding in the method at the University of Utrecht in the Netherlands. This step has borne rich fruits, as is shown by the wide acceptance of the Zürich-Montpellier method in South Africa following on its formal adoption as a standard method for surveys carried out by the Botanical Research Institute.

An aspect which has been of concern to this Institute for many years, and is not completely resolved yet (with some exceptions) is the lack of utilization of the results of ecological surveys in agriculture and planning. The new accent placed on catchment management by the Department of Forestry and the execution of ecological surveys to supply the basic information for such planning, may provide the turning point in this respect.

Let us hope that the obvious advantages to be reaped from scientific management and planning of the environment will induce those responsible to utilize to the full the valuable information contained in Dr Werger's work and in the many other available ecological publications. In this way if ecological planning, a field of study which urgently needs expansion, is to be successfully applied it will be stimulated and pursued to the advantage of the country as a whole.

B. DE WINTER
Director: Botanical Research Institute

Pretoria
1977-06-01

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Abstract

A phytosociological survey according to the concepts and methods of the Zürich-Montpellier School was carried out in the Upper Orange River valley. The study area is 656 km long and measures just over 3 000 km². in area. A small part of it falls in the temperate tropical zone while the main part falls in the semi-arid to arid zone. In a brief description of the area a complex gradient in climate, geological formation, geomorphological characteristics, soils, vegetation and land use is emphasized. The plant communities, their structure, habitat, and distribution in the study area are described. Three vegetation maps of various parts of the study area are presented. Based on the moisture regime of the soils, the communities are arranged in three parallel ecological series, which reflect a gradient from mesic to xeric conditions in species composition and community structure.

Uittreksel

'N FITOSOSIOLOGIESE STUDIE VAN DIE BO-ORANJERIVIERVALLEI

'n Fitososiologiese studie, waarin gebruik gemaak is van die konsepte en metodes van die Zürich-Montpellier-skool, is uitgevoer in die Bo-Oranjeriviervallei. Die studiegebied is 656 km lank en meer as 3 000 km² in oppervlakte. 'n Klein deel hiervan behoort tot die gematigde tropiese gebied, maar die grootste deel is semi-aried of aried. Die komplekse gradiënt in klimaat, geologiese en geomorfologiese struktuur, gronde, plantegroei en landgebruik word in die kort beskrywing van die studiegebied benadruk. Die plantgemeenskappe, hul struktuur, habitat en verspreiding word beskryf. Plantegroeikaarte van drie verskillende dele van die studiegebied is ingesluit. Die gemeenskappe word in drie parallelle ekologiese series gerangskik, gebaseer op die voghuishoudings van die gronde. Hierdie drie series reflekteer in hul soortesamestelling en plantegroeistruktuur die gradiënt van gematigde tot droë omstandighede.

Résumé

ÉTUDE PHYTOSOCIOLOGIQUE DE LA VALLÉE DU FLEUVE ORANGE EN SON COURS SUPÉRIEUR

On a exécuté une étude phytosociologique, selon les concepts et les méthodes de l'école de Zürich-Montpellier, dans la vallée du cours supérieur du fleuve Orange. La région étudiée a 656 km de long et sa superficie dépasse tout juste 3 000 km². Une petite partie de cette région se trouve en la zone tempérée-tropicale, mais tout le reste tombe dans la zone semi-aride à aride. Dans la brève description qui en est faite on souligne l'existence d'un gradient complexe du climat, de la conformation géologique, des caractéristiques géomorphologiques, des sols, de la végétation et de l'usage des terres. Les associations végétales sont décrites, avec leur structure, leur habitat et leur distribution dans l'aire étudiée. Trois cartes de végétation pour diverses portions de cette aire ont été dressées. En prenant pour base le régime hydrique des sols,on a arrangé les associations en trois séries écologiques parallèles qui reflètent, par leurs composants spécifiques et la structure des associations, un gradient des conditions mésiques vers xériques.

CHAPTER 1

Introduction

One hundred and sixty-four years after Bartholomew Dias discovered and named the Cabo de Boa Esperanza on 6 June 1488, the Vereenighde Oostindische g'octrooijeerde Compagnie established a revictualling station there, under the command of Jan van Riebeeck, to supply its ships en route to the Far East with fresh water, meat and vegetables. During the following century little exploration was undertaken into the interior, and some early settlers freed themselves from the authority and rule of the Company and started farming outside the borders of the early colony.

During his travels of 1761 to 1762 Hendrik Hop was the first European to reach the Orange River in Namaqualand and he referred to it as the Groote Rivier (Forbes, 1945). During 1772 to 1776 the Swede Sparrman travelled in the Cape Colony and although he did not reach the Orange River, he heard from Hottentots of the great river north of the Sneeuberg, that rose in the east and thereafter took a straight northward course. Sparrman related the great river of these stories to the Groote Rivier mentioned above that was reached and crossed earlier by Hendrik Hop.

Probably on 23 December 1777 Robert Jacob Gordon reached the Orange River near the present Bethulie and gave it its present name, herewith becoming the first effective discoverer of the Orange River north of the Sneeuberg (Forbes, 1949). Gordon was a Dutchman of Scottish extract, who came to the Cape Colony as a military captain in the Dutch garrison there and later became its commander. He called the spot where he reached the Orange River "De Fraaye Schoot", probably referring to good shooting of hippopotami there. He drew a wide panorama of the scene and described the country as all grassland and inhabited by Bushmen and Hottentots. Ten months later Gordon accompanied Governor Van Plettenberg on his travels into the interior during which they came to within a distance of 50 km of the Orange River in the vicinity of the present Colesberg, where Van Plettenberg erected his beacon. There is strong evidence that Gordon withheld information regarding the position of the river that he had reached the year before, in fear that the Governor would name the river after himself, whereas Gordon wanted it to bear a name in honour of the Prince of Orange. In 1779 Gordon, accompanied by the Englishman Paterson, travelled to the mouth of the Groote Rivier in Namaqualand, where he named it again Orange River. Gordon then travelled upstream along the Orange River as far as the vicinity of the present Prieska in order to ascertain if it was the same river that he had reached at "De Fraaye Schoot", whether it was navigable, to see the Aughrabies Falls, about which he had heard rumours, and to ascertain the exact course of the river (Forbes, 1948, 1949).

By 1825 colonists had settled on the major part of the area south of the Upper Orange River (roughly between 25° and 27° East), which was the official border of the Cape Colony. The farmers in this area were mainly nomadic pastoralists (Clarke, 1930). The area north of the Upper Orange River was inhabited by Sotho tribes in the extreme east and by Bushmen, Hottentots, Griquas and Corannas in the remaining part. Philippolis was the Griqua capital in those days, and near the present Bethulie lived a small refugee Bechuana tribe. Andrew Smith reported in 1834, that the white farmers regularly crossed the Orange River with their sheep to let them graze temporarily on the grasslands north of the Orange River, the veld south of the river having already being destroyed as it was covered with Karoo bushes. This frequently caused serious friction between these farmers and the Griquas (Kirby, 1939).

Incursions by the white "trekkers" across the Orange River and on to the eastern plateau assumed great importance with the advent of the Great Trek of 1836 which followed the route over the watershed between the westward flowing rivers and the Caledon (Clarke, 1930). This resulted in the establishment of the independent Afrikaner Republics north of the Cape Colony, and ultimated in the proclamation of the Republic of South Africa in 1961.

Towards the end of the nineteenth century and the beginning of the twentieth, water was pumped out of the Great Fish and Sundays rivers in the eastern Cape for irrigation purposes. Dams were constructed locally to provide for a regular distribution of water throughout the year, but run-off from the catchment areas proved to be inadequate to provide proper irrigation and prosperous economic. development. Thoughts

turned to the possibility of diverting the water from the Upper Orange River towards the Great Fish and Sundays rivers by means of an 80 km long tunnel; a plan, proposed by the Director of Irrigation as far back as 1928. Lack of financial means made this proposal impracticable (Alexander, 1966).

By 1903 Willcocks had already proposed a plan for building a high diversion weir at the Vanderkloof site, where at present the P.K. le Roux Dam wall is nearing completion, in order to irrigate land as far downstream as Prieska.

In 1928, Lewis discussed the future development of the Orange River and came to the conclusion that large storage dams had to be constructed to provide water for irrigation, as well as to control the devastating floods that occurred periodically. This and similar ideas appealed to the settlers in the Lower Orange River area, and a number of proposals were worked out to develop the Orange and Great Fish - Sundays rivers areas. Apart from the demands of the farmers, the municipalities of the major urban centres in these areas demanded an increase in their water resources while developing industries created a demand for electric power which could be generated by hydro-electric stations. This ultimately, led to the formulation of a comprehensive development plan for the Orange River, to provide for the requirements of irrigation, urban water supply, hydro-electric power development and flood control. The plan will be developed in stages and comprises a huge storage dam near Norvalspont, an 83 km long tunnel from Oviston to a Great Fish River tributary, a second, shorter tunnel from there to the Sundays River, a high storage dam near Petrusville to provide irrigation water in a large area further downstream, and a third dam at Torquay for similar purposes. In 1961 these proposals were approved by Parliament and in the following year a start was made with the construction of the Hendrik Verwoerd Dam and the Orange-Great Fish River tunnel (Alexander, 1967a, b). In September 1970 the dam wall was closed and the water started damming up behind the wall (Fig. 1). After exceptionally good rains in the Upper Orange River catchment area in the 1971 to 1972 season the Hendrik Verwoerd Dam spilled over for the first time on 29 February 1972.

The development of this comprehensive water development scheme in the Orange River area, gave rise to a wide range of basic and applied scientific surveys of that area. The reasons for these surveys were threefold: (1) The huge capital investment on such a water scheme can only be justified economically on a long term basis. This means that the waterworks must be protected over a long period of time against silting and this necessitates studies of the catchment area. (2) In order to enable effective long term planning regarding the management and use of the natural resources in the area, it is necessary to know the state of the local ecosystems before any major changes are made. (3) From an academic point of view it is of utmost interest to study alterations in an area that is due to undergo so much artificially induced change in a short period of time. All three reasons require studies to be made of the area before the changes are made.

This account reports on one of these surveys, namely an inventory of the plant communities of the Upper Orange River valley. The part of the survey that covers the riverine vegetation is included in topic 6 ORDS project 6.3 of the Orange River Workgroup and subproject 8.5 of the IBP PF (International Biological Programme, section Productivity of Freshwater). This survey

FIG. 1 - Verwoerd Dam (1973). View from southern shore in the vicinity of Oviston

was registered as research project No. (A)P-Pr.24 of the Department of Agricultural Technical Services.

An inventory of plant communities of a certain area, if done in a scientifically sound way, can serve as a basis for further basic scientific work of academic interest as well as for applied scientific work orientated towards management. Because of the deteriorated condition of the veld in the Upper Orange River catchment area, erosion is severe and therefore holds a serious threat over the economic and functional existence of the large waterworks presently under construction. Therefore, a survey on the grazing potential, condition and erosion status of the veld was undertaken in four areas, together comprising the Orange River catchment area upstream from the Hendrik Verwoerd Dam. The veld was mapped in floristical dominance types, subdivided according to condition and erosion status, to a scale of 1:50 000.

Classifying a vegetational cover in dominance types is only of restricted value, however, and it was felt that a more scientifically based classification would be advantageous. The present survey was therefore undertaken to inventorize and describe the plant communities occurring in the area. Because a survey of the whole Upper Orange River catchment area would take too many years for the one surveyor that was available, the survey was restricted to the Upper Orange River valley. The interpretation of the word "valley" was taken in its widest sense and is defined later. It was thought that the plant communities found in the survey area should provide possibilities of extrapolating into a wide area of the Orange River catchment area, especially into the Highveld region, where other surveys are underway at present, and into the Karoo. Thus, this report should provide information on an extensive part of the central regions of the Republic of South Africa.

The area

The longest river in Africa south of the Zambezi and the largest river in the Republic of South Africa is the Orange River. It is also the only river in southern Africa to rise on one edge of the African plateau and to flow to the opposite edge (Wellington, 1955). From its source in the Drakensberg in Lesotho, where it is called Sinqu, down to its mouth in the Atlantic at Alexander Bay, the distance along the longitudinal river profile is approximately 2 200 km. With its source at Mont aux Sources at an altitude of 3 300 m, this gives an average gradient for the whole Orange River of 1,5 m per km. The Vaal River, the Orange River's greatest tributary, joins the Orange River about 16 km downstream from Douglas and is longer than the Orange River upstream from the confluence. Taking the Vaal headwater as the main stream, the river measures 2 500 km along its longitudinal profile. However the branch that rises in Lesotho has always been considered to be the main stream (Fig. 2).

The Orange River basin covers 650 000 km^2 and is the largest river basin south of the Zambezi that has an outlet to the sea. The only larger one is the Kalahari basin, that measures 1 290 000 km^2, but nearly half of it is areic and the remaining part endoreic. Part of the Kalahari basin, the Molopo-Nossob system, formerly drained into the Orange River. More than 1 000 years ago this drainage was blocked by wind-blown sand and the rare flood-waters now drain into Abiquas Puts. With this typical feature of blocking river courses by wind-blown sand, this system can be regarded as being part of the endoreic half of the Kalahari basin (Wellington, 1955, 1958). Moolman (1946) considered the Molopo-Nossob system to belong to the Orange River basin.

On its way from its origin in the humid Drakensberg, the main watershed of South Africa, through the semi-arid and arid areas down to the Atlantic, the Orange River traverses nearly the whole succession of geological formations found in southern Africa: from the relatively young basalts, sandstones, shales and tillites of the Karoo system to the granites, lavas and quartzites of the Archaean complex. On its general east-west course it also flows through a diversity of soil types: from the black clay soils in the Drakensberg and the prairie soils of the Highveld to the Kalahari sands and the desert soils of Bushmanland and Namaqualand. A series of veld types is crossed: from the alpine and Highveld grasslands, the open shrublands of the Karoo to the semi-desert and succulent vegetation types of the Namaqualand Broken Veld, the Succulent Karoo in the Richtersveld, and the desert vegetation of the southern Namib near Alexander Bay. Taking the total diversity of the physical environment into account, the Orange River is usually divided into three physiographic sections (Wellington, 1933): the Upper Orange River from its origin at Mont aux Sources down to its confluence with the Vaal River; the Middle Orange River from the Orange-Vaal confluence down to Aughrabies Falls and the Lower Orange River from Aughrabies Falls down to the mouth in the Atlantic Ocean. This report deals with the ecology and plant communities of the Upper Orange River only (Fig. 3). Therefore, the physical environment and human history of that part will now be described in more detail.

2.1 TOPOGRAPHY AND HYDROLOGY

When the Orange River at the confluence with the Telle River, near Palmietfontein, becomes the border between Lesotho and the Republic of South Africa, its altitude has dropped from about 3 300 m at its origin at Mont aux Sources to 1 398 m. Twenty-six kilometres further downstream it is joined by the Kornetspruit, which forms the border between Lesotho and the Republic of South Africa to the north of this point, just as the Telle River does further to the south. Here the Orange River actually enters South Africa, forming the border between the Orange Free State and the Herschel area of the Ciskei which is bordered on the north by the Orange River as far as the point where the Wilgespruit enters the Orange, 146 km downstream from the Orange-Telle confluence. Aliwal North, the main centre for a large area, is situated 139 km downstream from the Orange-Kornetspruit confluence. Just upstream of Aliwal North the Orange is joined by the Kraai River, the main drainage channel of the north-eastern Cape. At Aliwal North the height of the riverbed is 1 296 m. At Goedemoed the water of the Orange River is used to irrigate the fields of the

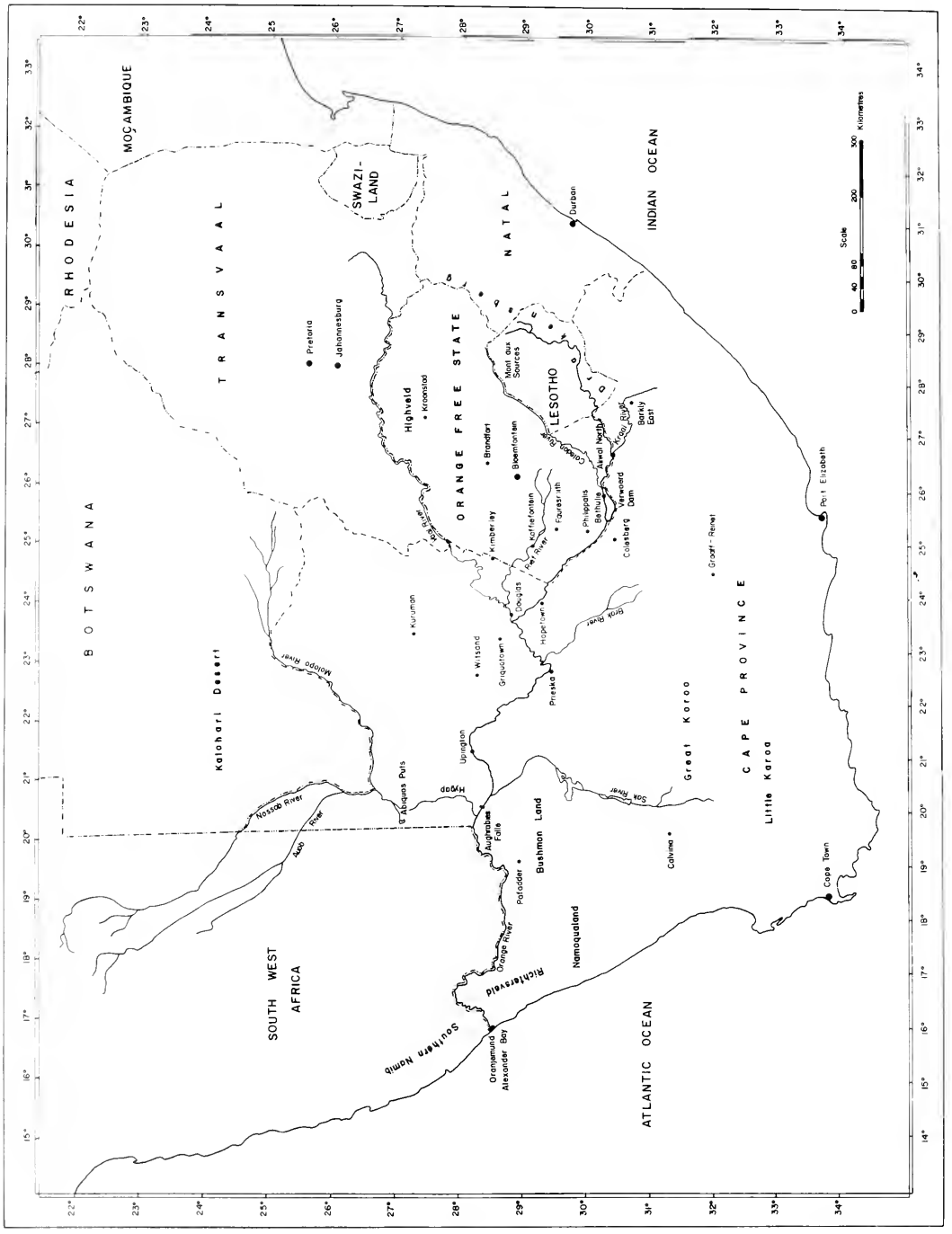


FIG. 2 - Map of southern Africa showing the course of the Orange River

local prison farm. Further downstream the Orange River reaches the Tussen die Riviere Game Farm and forms more or less its southern boundary. When the Hendrik Verwoerd Dam is filled to total capacity at its initial dam wall level the water reaches this Game Farm. Just before the Upper Orange River leaves Tussen die Riviere Game Farm, 89 km downstream of Aliwal North, it is joined by its second largest tributary, the Caledon River. This tributary is a perennial stream that drains western Lesotho and the eastern Orange Free State. Ten kilometres further downstream the combined waters of the Orange and Caledon Rivers reach Bethulie. Forty-one kilometres downstream from Bethulie on the Cape side lie the villages of Venterstad and Oviston at the entrance of the 83 km long Orange-Fish tunnel which brings the water of the Orange River to the Fish River and from there through a second tunnel to the Sundays River (Jordaan, 1962 to 1963). In this way part of the water of the Orange River reaches the Indian Ocean. The wall of the Hendrik Verwoerd Dam has been built at Oranjekrag 80 km downstream from Bethulie and 318 km downstream from the Orange-Kornetspruit confluence.

The Hendrik Verwoerd Dam is to be the main storage dam to regulate the flow of the Orange River and provide sufficient extra storage capacity for silt deposits. It is planned to raise the dam wall in a number of successive stages over 120 years in order to maintain enough storage capacity against silt deposits. When full, the Hendrik Verwoerd Dam at its present dam wall level has a surface area of approximately 700 km² (Jordaan, 1962-63; 1964-65; Kriel, 1971-72).

The altitude at the foot of the wall is 1 193 m and 5 km downstream is the village of Norvalspont. The proposed P.K. le Roux Dam, that is under construction near Petrusville, 121 km downstream from Oranjekrag, will, when full, push the water back as far as the farm Skurwekop 60 km below Oranjekrag. This P.K. le Roux Dam lake will be narrow and deep. At the foot of its wall the altitude is 1 098 m. From here long canals will branch out to irrigate the area between the P.K. le Roux Dam and Hopetown and possibly even further (Kriel, 1971-72). The right bank canal will supply water to the Riet River valley. Ninety-six kilometres downstream from this dam is the road bridge near Hopetown. From Hopetown to the proposed site of the Torquay Dam wall is a distance of 51 km. The altitude of the river bed at Torquay is 1 000 m. The Torquay Dam will push the water back to just below the old road bridge downstream of Hopetown. The Torquay Dam is planned to serve irrigable land on the right bank of the Orange between Torquay and Douglas, as well as land along the Middle Orange River and the Brak River towards Prieska. The dam is also planned to be used for the generation of hydro-electric power.

The distance from the Torquay Dam site to the Orange-Vaal confluence at Mazelsfontein is 44 km and here the altitude of the river bed is 974 m.

From the Orange-Kornetspruit confluence to the Orange-Vaal confluence at Mazelsfontein the distance along the longitudinal profile of the river measures 630 km. This brings the average gradient of the Upper Orange River within the Republic of South Africa as far as this point to 0,65 m/km. Detailed data on the gradient in all sections of the Upper Orange River have been supplied by Werger (1973b).

At the Orange-Vaal confluence the river enters a new physiographic region known as the middle course of the Orange River, and leaves the present study area.

The direction of the Upper Orange River is WSW from the Orange-Kornetspruit confluence to Aliwal North, WNW from Aliwal North to Tussen die Riviere Game Farm, from Tussen die Riviere Game Farm to Venterstad again WSW and from here to the Orange-Vaal confluence the river takes a NW course (Fig. 3).

The only perennial tributary of the Upper Orange River is the Caledon River. According to Wellington (1955), who bases his information on data from the period 1919 to 1935, the average number of days of flow of the Caledon during the year is 359. The mean annual flow of the Caledon during this same period was $1{,}1.10^9$ m³, the minimum $2{,}5.10^8$ m³ and the maximum $3{,}3.10^9$ m³. March, January and November in that order were the months with the highest flows, and June the month with the lowest. Flow was measured at a gauge near Wepener above where the catchment area is 13 300 km² in extent.

During the period 1913 to 1945 data were collected at a gauge located at the railway bridge at Orange River Station, 15 km upstream from Hopetown, the catchment of the river above the gauge measuring 95 300 km². The mean annual flow here was $7{,}6.10^9$ m³, with a minimum of $1{,}4.10^9$ m³ and a maximum of $19{,}4.10^9$ m³. The peak flow was during March, followed by January and February. The lowest flow occurred during August. The mean number of days of flow were 364 days annually (Wellington, 1955).

By means of sampling over long periods, the silt load of the Orange River at Bethulie was determined as 0,80 % of the run-off; at Aliwal North this figure was 0,56 %. The Caledon provided 22,3 % of the mean annual flow to the Hendrik Verwoerd Dam and 23 % of its silt load. This 22,3 % consisted of 10,5 % from Lesotho and 11,8 % from the area within the Republic of South Africa. The Kraai River contributed 12,5 % of the water and 22,2 % of the silt load. The remainder of the catchment between Lesotho and the Caledon contributed 10,1 % of the flow and 23,9 % of the silt load (Jordaan, 1962-1963; Commission of Inquiry, 1970).

The run-off into the Orange River downstream of Bethulie measured as a percentage of the average rainfall over the catchment area was 1,6 %; the figure for the Orange and Caledon Rivers upstream of Bethulie was 14,0 % (Commission of Inquiry, 1970).

Although the Orange River is a perennial stream with flow peaks towards the end of the rainy season and flow minima during mid-winter, the water flow is not at all regular. Destructive floods, which inundate the banks and bring down much silt and sand, are not rare. Exceptional floods have been recorded at Hopetown where in February 1874 a flood of more than 11 000 m^3/sec occurred and on 24 March 1925 a flood of about 9 000 m^3/sec was registered (Jordaan, 1962-1963). In 1967 a discharge of 10 500 m^3/sec was recorded at Bethulie (Commission of Inquiry, 1970). With the present storage capacity of the Hendrik Verwoerd Dam the frequency of these floods will be reduced by 50 %, and will be further reduced when the dam wall is raised in the future. Obviously this will have its impact on the riverine communities downstream of Goedemoed. Possibly there will also be a slight change in the air humidity in the immediate neighbourhood of the large water surfaces, since the mean annual evaporation from the Hendrik Verwoerd and P.K. le Roux Dams together is estimated at 512 million m^3 (Kriel, 1971-1972).

2.2 CLIMATE

The entire area of the Upper Orange River is subject to a summer rainfall climate, although there are significant differences along the east-west gradient. According to Kendrew (1961) the weather is dominated by subtropical anticyclonic high pressure systems, which, in winter, are centered at about latitude 28 °S and, in summer, at about 33 °S. Therefore, the winters are calm and almost rainless and are characterized by clear skies and light winds, mainly in the westerly quarter. Frosts occur regularly, particularly from May to September. In particular the area around Sterkspruit may be covered with snow for some days during the winter season when outbreaks of cold humid air from the south sweep across the Karoo and Highveld. In summer the land is heated by a sun which is nearly overhead, causing the pressure to fall. Moist maritime tropical air from the Indian Ocean is drawn onto the continent, bringing clouds and rain from the north. This does not mean, however, that the skies are usually cloudy during summer. On the contrary, skies are usually clear, causing high diurnal ranges in temperature, and the precipitation comes mainly from violent thunderstorms. Rainfall is highest in the higher lying areas in the east and decreases rapidly along the westward course of the Upper Orange River. Most of the area can be regarded as semi-arid (Jackson, 1951; Kendrew, 1961).

Detailed climate statistics are available from eleven stations along or near the Upper Orange River (Weather Bureau, 1954, 1965b, 1967a, b, 1968, 1970, 1971) and are reproduced in Werger (1973b). Stations situated on the Orange River are at Aliwal North, Bethulie, Oviston, Hendrik Verwoerd Dam, P.K. le Roux Dam and Hopetown, whereas Mohaleshoek, Venterstad, Fauresmith, Andriesfontein and Griquatown are located up to as far as 75 km from the Orange River. Statistics from these eleven stations have been used to draw up climatic diagrams as proposed by Walter & Lieth (1960) (Fig. 4). Venterstad, Oviston, Hendrik Verwoerd Dam and P.K. le Roux Dam have records over only a short period of time. The altitudes of all weather stations have been obtained from the publications of the Weather Bureau. These values may differ occasionally from those of the 1:50 000 topographical maps.

A detailed description of the climate of part of the area with special regard to agricultural purposes is given by Whitmore (1950a, b, c).

2.2.1 Cloudiness

Cloud cover statistics are available from only four stations near the Upper Orange River, namely Aliwal North, Bethulie, Fauresmith and Andriesfontein (Weather Bureau, 1954).

The cloudiness is far greater in the afternoon than in the morning and there seems to be a slight increase in cloudiness from east to west. There is a double period in cloudiness during the year with a first and absolute maximum in February-March and a second minor maximum during October-November. The maximum during February-March coincides with the maximum in precipitation. The periodicity in cloudiness is related to the seasonal change in general circulation of the atmosphere. The high pressure belt that is located above the southern Karoo area during summer, shifts north toward the Highveld region where it is located during winter. As the high pressure belt passes over in February-March and October-November, it brings an increase in cloudiness.

2.2.2 Sunshine

Statistics on the duration of sunshine are available from only two stations located near the Upper Orange River, Aliwal North and Fauresmith (Weather Bureau, 1965a). Generalized maps of the Weather Bureau (1950) combined with figures from these two stations show that the Upper Orange River area falls completely within a zone where the average annual duration of bright sunshine is between 70 % and 80 % of the possible sunshine. In January the whole area also falls into this zone, whereas in July the whole area falls into a zone of 80 to 90 % of the possible sunshine. It is not surprising that the period of maximum sunshine coincides with the period of minimum cloudiness.

There appears to be a double period in the amount of sunshine, which agrees inversely with the periodicity of cloudiness. It is interesting to note, however, that the driest month (June) is not the month with the highest amount of sunshine. Although June is the driest month, the cloudiness reaches its minimum during August or July, thus giving the maximum sunshine during this time of the year. March, being the wettest month, shows the lowest amount of sunshine and a high cloud cover. Since this "low" amount of sunshine is

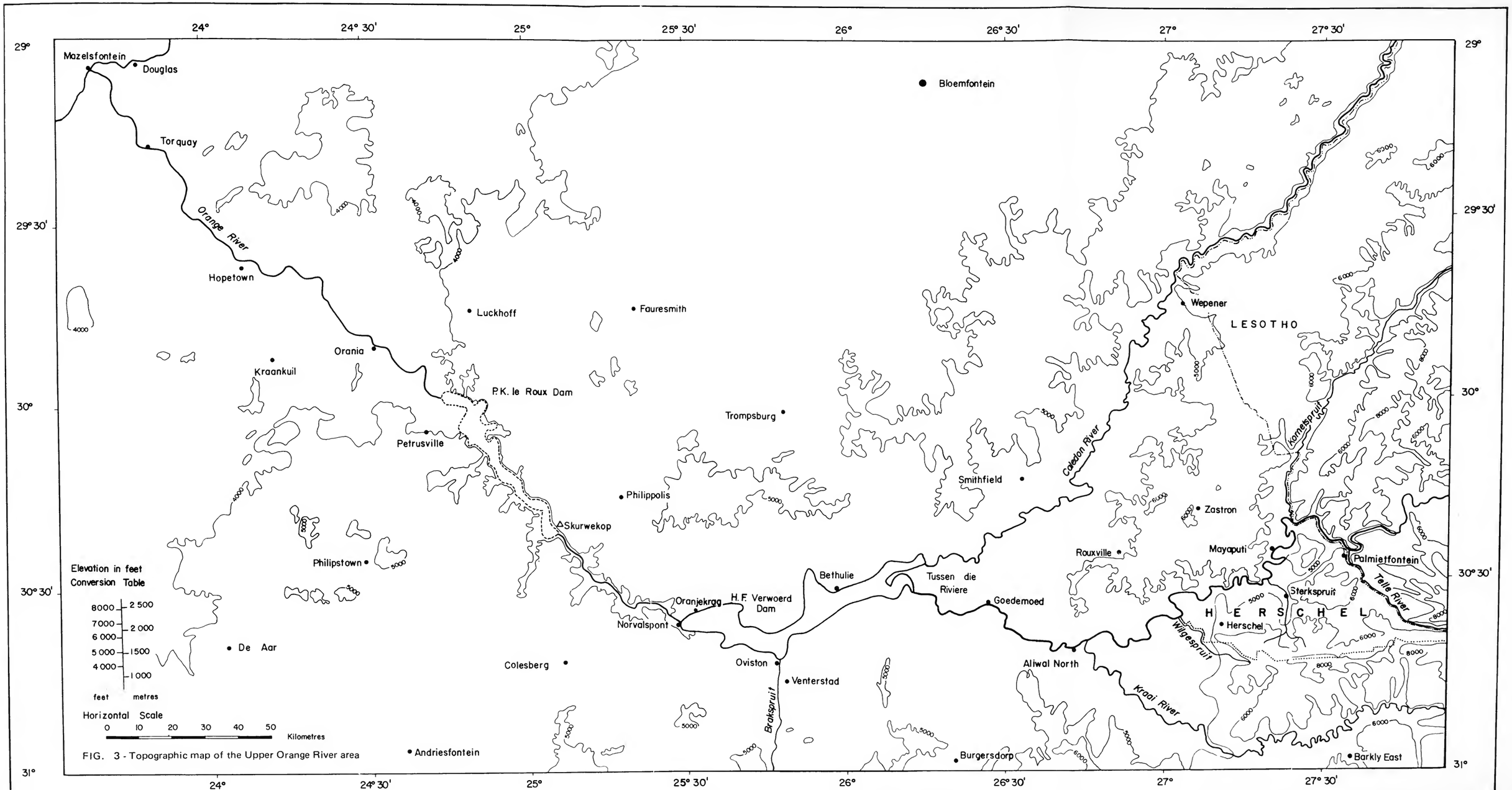


FIG. 3 - Topographic map of the Upper Orange River area

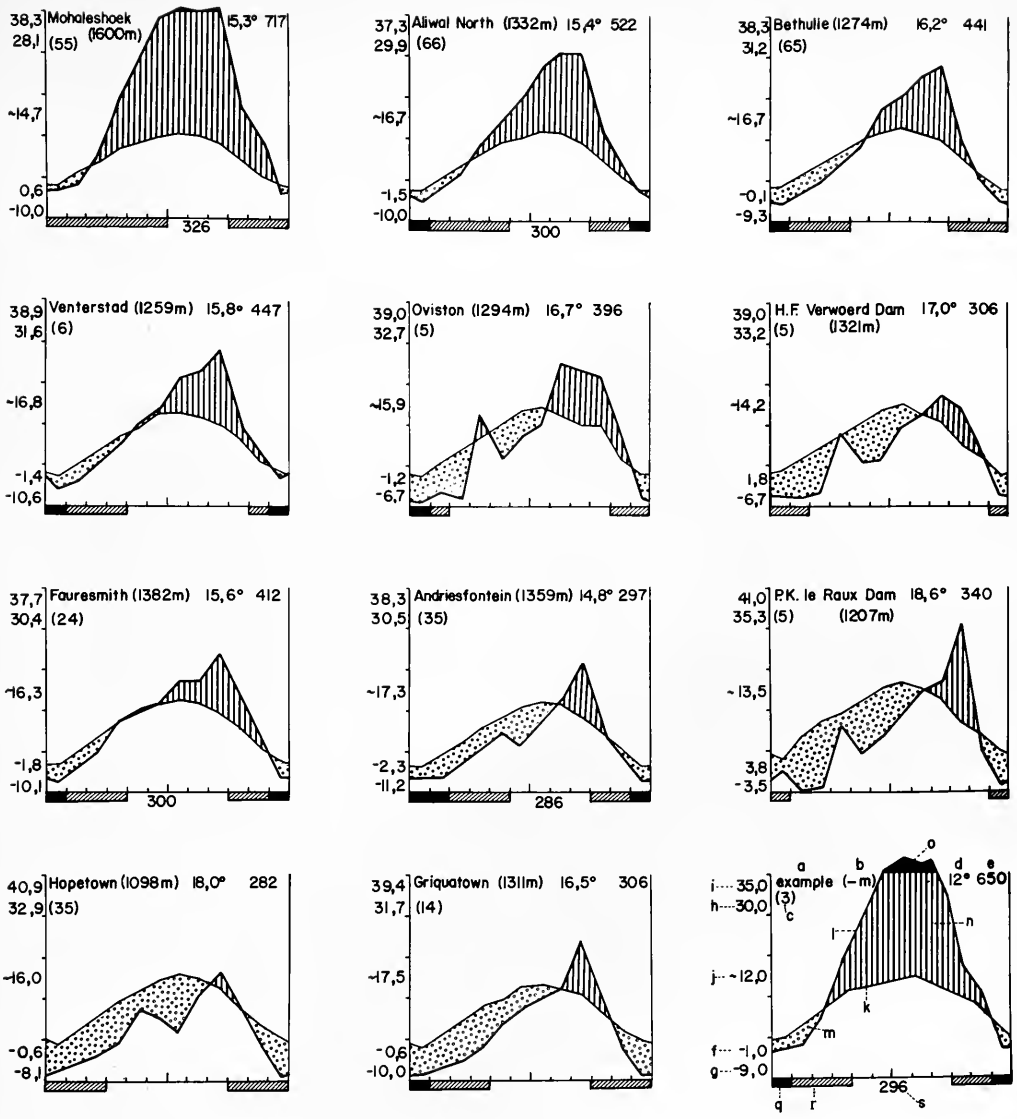


FIG. 4 - Climate diagrams of eleven stations in the Upper Orange River area.

LEGEND (see example in bottom right hand corner)

Twelve month period starts with July on left hand side.

(a) Name of station; (b) Altitude (m); (c) Number of years of observation; (d) Mean annual temperature (°C); (e) Mean annual precipitation (mm); (f) Mean daily minimum temperature of coldest month; (g) Absolute minimum temperature; (h) Mean daily maximum temperature of hottest month; (i) Absolute maximum temperature; (j) Mean range of temperature; (k) Curve of mean monthly temperature (1 unit = 10 °C); (l) Curve of mean monthly precipitation (1 unit = 20 mm); (m) Dry season; (n) Wet season; (o) Mean monthly precipitation over 100 mm (reduced to 1/10); (q) Months with mean daily minimum temperature under 0 °C; (r) Months with absolute daily minimum temperature under 0°C; (s) Mean duration of frost free period (days)

TABLE 1 - Average duration of frost period and number of frost days

Station	Mohaleshoek	Aliwal North	Fauresmith	Andriesfontein	Hopetown	Griquatown
SL	30° 09'	30° 41'	29° 46'	30° 57'	29° 37'	28° 51'
EL	27° 28'	26° 43'	25° 19'	24° 36'	24° 05'	23° 15'
Altitude (m)	1 600	1 332	1 382	1 359	1 098	1 311
Period (years)	28	16	20	25	11	16
Average duration of frost period (days)	138	135	132	165	102	127
Average annual number of frost days	38,8	65,4	64,9	78,9	-	-

nevertheless still 72% for both Aliwal North and Fauresmith at the time of maximum precipitation, and since Aliwal North and Fauresmith during March still record 25 and 27,9 days with more than 50% of the possible sunshine respectively, this accounts for the fact that the rainfall in the Upper Orange River area loses much of its effectiveness.

2.2.3 Temperature

Records of temperature have been kept by eleven stations along or near the Upper Orange River. The monthly average of the mean daily temperature (half the sum of the daily maxima and minima) are expressed in Fig. 4. The mean yearly temperature, the absolute highest temperature, the absolute lowest temperature, the average daily minimum for the coldest month, the average daily maximum for the warmest month, the annual average of the daily range in temperature, the months with an average daily minimum temperature lower than 0 °C, the months with an absolute minimum lower than 0 °C and the mean duration of the frost free period are also given in Fig. 4. Temperature is recorded at 1,20 m above the ground at every station.

From Fig. 4 it can be seen that the mean monthly temperatures of all the stations show an almost regular sinusoidal pattern, with a maximum in January and a minimum in July. Only Hendrik Verwoerd Dam shows a minimum in June, but this can possibly be as a result of the short period of observation.

Temperature is to a large extent dependent on topography (Geiger, 1965). This is shown clearly by comparing the values at P.K. le Roux Dam, a station situated in a narrow, deep valley, and those at Mohaleshoek, which has, probably due to its sheltered situation in the mountains, a relatively high mean July temperature, although the station lies at 1 600 m. The lowest mean July values are recorded at Andriesfontein and Fauresmith, both lying on the plateau. The stations along the Orange River stream-bed, Aliwal North, Bethulie, Oviston, Hendrik Verwoerd Dam, P.K. le Roux Dam and Hopetown, show a gradual increase down the river in mean January temperatures. P.K. le Roux Dam shows the highest temperatures, which fact is probably related to local topographical features. Differences between the mean temperatures of the warmest month of the eleven stations are larger than those between these values during the coldest month. There is a considerable diurnal change in temperature at all stations in the Upper Orange River area, particularly during the coldest time of the year. This considerable diurnal change in temperature, which is consistent over the whole year, is the cause of the high value for the mean annual range in temperature that is characteristic of the central part of South Africa. The annual average of the daily range in temperature differs from 13,5 °C at P.K. le Roux Dam to 17,5 °C at Griquatown and tends to be lowest at the sheltered stations.

The average daily minima for the coldest month (July) are, except at Hopetown and at the sheltered stations P.K. le Roux Dam, Mohaleshoek and Hendrik Verwoerd Dam, all below freezing point. The lowest values are again found at the plateau stations Andriesfontein and Fauresmith. The absolute minimum temperatures recorded at these stations do not differ much from most of the other stations, however, with the exception of P.K. le Roux Dam. Three stations, Bethulie, Oviston and Griquatown, have only one month with a mean daily temperature below freezing point, while three, Aliwal North, Venterstad and Fauresmith, experience two months with a mean daily temperature below freezing point, and at Andriesfontein this period is three months.

The number of months with an absolute daily temperature lower than 0 °C differ considerably from station to station. P.K. le Roux Dam has recorded only two, Hendrik Verwoerd Dam three, Oviston four, Venterstad and Hopetown six, Bethulie, Fauresmith and Griquatown seven, Aliwal North and Andriesfontein eight and Mohaleshoek nine. It should again be emphasized that the first three stations have only kept temperature records for five years. At six stations the period over which frost occurs and the number of days with frost have been recorded. The data are listed in Table 1.

The occurrence of frost is also strongly related to topography. Owing to the high altitude and the sheltered position of Mohaleshoek, the average duration of the frost period is slightly higher than at Aliwal North and Fauresmith, but the actual average number of frost days is just over half of the number at these last two stations. Andriesfontein shows the lowest absolute minimum temperature, the longest average frost period and the largest number of frost days.

The average daily maxima for the warmest month (January) show a slight increase following the course of the river, with exceptions for the plateau stations Fauresmith and Andriesfontein, and with a maximum value at P.K. le Roux Dam. Although there is a temperature increase over South Africa from east to west, in considering these values of average daily maxima for the warmest month, it should be kept in mind that there is also a decrease in altitude of the stations from east to west. The absolute maxima for the eleven stations do not differ very much from one another. The highest value is again recorded at P.K. le Roux Dam.

2.2.4 Wind

Records on wind direction and speed have been kept by two stations along or near the Upper Orange River, Bethulie and Fauresmith, for 10 years (Weather Bureau, 1960). These records show clearly that the prevailing wind direction over the whole year is NW at Bethulie and between NW and N at Fauresmith. At Fauresmith winds of over 60 km/h have never been recorded and at Bethulie only occasionally. Apart from the general wind from the NW, short but strong winds occur from

the southwesterly sector during summer. They are almost always associated with thunderstorms. During hot summer days whirlwinds or dust-devils occur over the entire Upper Orange River area. They are caused by strong convection. Duststorms, associated with thunder conditions, also occur infrequently over the area. They are favoured by the small amount of plant cover in the area.

2.2.5 Relative humidity and saturation deficit

Relative humidity of the air is the direct measure of the degree of moistness of the atmosphere irrespective of its temperature. Records on mean, maximum and minimum relative humidity have been kept by four stations along or near the Upper Orange River (Weather Bureau, 1954, 1965a). It can be concluded that the average annual relative humidity at 14h00 tends to decrease slightly in a westward direction. Around March the mean relative humidity is highest with values of 40 %. This is the same period at which the precipitation is maximal. The lowest average relative humidity at 14h00 is usually reached during early summer (December) in the Upper Orange River area with values of about 25 %. The relative humidity is not inversely correlated with temperature in the Upper Orange River area because the influx of moist air in the warm season is sufficient to counteract the effect of rising temperature (Weather Bureau, 1965a). In the Upper Orange River area the periodicity of the variation in relative humidity falls midway between temperature and rainfall periodicity.

The diurnal variation in relative humidity at each station is large. It is more or less inversely correlated with the diurnal variation in temperature. In winter the diurnal variations of relative humidity and of temperature are at their maxima.

Saturation deficit is not directly proportional to evaporation since the latter is also dependent on other factors such as wind velocity. Maps from the Weather Bureau (1965a) show that in January the entire Upper Orange River area falls in the zone where the mean saturation deficit at 14h00 is between 25 mb in the east and 40 mb in the west. In July these values are betweeen 12 mb in the east and 15 mb in the west. Thus, the mean saturation deficit at 14h00 in the Upper Orange River area shows a gradient that increases westward and correlates with the temperature gradient and with the inverse of relative humidity. The mean saturation deficit at 14h00 in the Orange River area is lowest during winter and highest during summer. The gradient from east to west is steepest in summer.

The diurnal change in saturation deficit in the Upper Orange River area is large and, according to a tentative map of the Weather Bureau (1965a), larger in summer (between 20 and 25 mb) than in winter (between 12 and 15 mb).

2.2.6 Evaporation

Only two stations, Aliwal North and Fauresmith, that keep records on evaporation, are located close enough to the Upper Orange River to be discussed here. The evaporation is measured by means of a class "A" evaporation pan and records have been kept over a period of four years. These records indicate that as in the case of the saturation deficit and the temperature, evaporation also shows an increase in the downstream direction of the Orange River. The annual range in evaporation also tends to increase in this direction. The evaporation is highest during early summer (December, 284 and 366 mm at Aliwal North and Fauresmith respectively) and lowest during early winter (June, 64 and 81 mm respectively). The time of minimal evaporation coincides with the time of lowest precipitation.

2.2.7 Precipitation

Rainfall statistics are available from 49 stations in or near the Orange River valley (Weather Bureau 1965a, b, 1968, 1970, 1971). Data are given in Table 2.

It can be seen from Table 2 that the precipitation decreases along the river course from a mean annual amount of over 600 mm to less than 300 mm. The maximum amount of rain generally falls during March, although a few local deviations may occur. Should the precipitations during March in any particular year not be the maximum for that year then March is usually the month with the second highest precipitation, with figures close in value to the highest amount. In a number of cases exceptions will be due to the short period of recording, like the October values for Oviston. The driest month is usually June, although frequently July also shows the lowest rainfall figures. This suggests that for the entire Upper Orange River the driest time of the year is during the second half of June and the first half of July. The asymmetrical distribution of the precipitation over the year is clearly shown in Table 2. After the maximum in March, the minimum is reached very soon, then there is a gradual increase over the year towards the maximum. The rainfall map of Mackenzie (1945) shows that the 25 inch (635 mm) isohyet forms a large eastward pocket between Herschel and Zastron, and reflects some correlation with the topography of the area. Just downstream of Aliwal North the 20 inch (508 mm) isohyet crosses the Orange River. The 15 inch (381 mm) isohyet forms an eastward pocket between Venterstad and Bethulie and runs from there more or less parallel and to the right of the Orange River valley as far as the vicinity of Petrusville, where it turns northward. On its parallel tract this isohyet just crosses the valley north of Colesberg. The rainfall figures for Rietbult confirm this. In the same way the low rainfall figures for Bakovenspan reflect the eastward pocket of the 10 inch (254 mm) isohyet between Hopetown and De Aar.

TABLE 2 - Rainfall data of the Upper Orange River valley

Station	S. lat.	E. long.	Alt. (m)	Distance from river-bed (km)	Period (years)	Average rainfall (mm)											
						Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Palmietfontein	30° 25'	27° 32'	1326	1,5	10	122,7	100,3	94,2	64,0	34,0	20,3	11,9	13,5	40,9	56,1	62,0	97,3	717,2
Kornetspruit	30° 16'	27° 21'	1486	5,0	35	82,3	83,9	95,9	52,4	28,3	10,7	15,2	16,2	27,5	58,8	71,6	95,4	638,2
Halma	30° 23'	27° 23'	1478	1,0	29	79,3	85,3	86,8	56,0	35,7	9,6	14,0	14,2	24,9	50,2	70,4	93,3	619,7
Sterkspruit	30° 31'	27° 22'	1454	7,0	60	93,4	97,1	98,5	52,1	32,0	12,2	12,8	13,2	31,1	50,6	68,1	90,8	651,9
Quaggafontein	30° 28'	27° 14'	1372	2,5	32	71,4	72,2	94,8	49,0	29,2	7,5	12,4	12,5	25,5	44,0	56,6	73,3	548,4
Herschel	30° 37'	27° 10'	1554	8,0	66	97,6	95,3	103,1	57,2	35,4	16,0	13,4	20,5	29,9	51,9	66,6	82,3	669,2
Broederstroom	30° 32'	27° 01'	1341	1,5	20	78,7	76,1	80,2	55,0	30,6	8,4	10,4	17,9	22,1	53,1	53,5	59,5	545,5
Morgenson	30° 38'	27° 02'	1417	3,5	26	84,0	75,5	87,0	48,5	37,4	7,0	12,6	15,1	20,4	48,4	66,5	57,8	560,2
Klipdam	30° 35'	26° 55'	1370	3,5	6	79,0	84,4	92,9	47,0	36,6	3,9	4,1	11,5	18,2	50,7	86,8	49,1	564,2
Lusthof	30° 38'	26° 48'	1370	2,0	7	72,1	77,6	80,3	36,8	32,3	6,7	12,7	9,7	25,8	36,4	59,1	63,3	512,8
Aliwal N - prison	30° 41'	26° 43'	1356	0,0	71	75,2	80,9	81,4	44,5	28,1	13,2	10,2	15,7	23,3	39,0	53,9	62,1	527,5
Aliwal N - municipality	30° 42'	26° 42'	1356	0,0	60	89,7	95,0	94,2	46,2	27,7	16,0	13,0	17,5	24,1	39,1	58,9	70,6	592,0
Sanddrift	30° 37'	26° 30'	1295	0,0	18	57,3	69,2	70,6	60,0	37,3	5,6	8,5	13,0	11,0	31,5	48,0	48,4	460,4
Erfeniskraal	30° 33'	26° 26'	1372	2,0	24	45,7	57,7	72,9	20,0	16,5	8,6	7,6	11,9	29,1	28,7	41,4	42,4	382,4
Goedemoed police	30° 33'	26° 26'	1311	0,0	42	63,3	61,0	79,2	42,2	26,2	7,4	10,5	14,1	19,4	33,8	58,6	57,6	473,3
Oudefontein	30° 35'	26° 21'	1326	1,0	5	53,6	90,9	70,1	43,4	34,0	10,4	6,1	8,1	12,2	20,8	30,2	83,1	462,9
Wintershoek	30° 29'	26° 12'	1372	1,5	28	47,8	53,5	76,1	41,5	22,7	4,1	9,2	9,8	16,8	28,1	37,8	49,5	396,9
Eerstestap (x)	30° 32'	26° 02'	1311	0,0	30	50,8	53,6	66,8	33,3	16,5	5,1	5,3	12,7	17,3	25,7	42,2	40,6	369,9
Bethulie	30° 30'	25° 58'	1274	4,0	67	61,1	71,3	74,8	41,2	21,1	9,7	8,9	11,7	19,4	30,1	37,9	53,9	441,1
Luckno (x)	30° 32'	25° 55'	1265	0,0	29	46,1	55,8	62,1	44,6	28,2	5,1	9,3	10,4	17,1	26,5	37,7	43,3	386,2
De Rust (x)	30° 40'	25° 50'	1356	3,0	18	51,3	44,7	50,0	36,1	18,8	6,6	8,6	14,5	24,9	28,2	41,9	35,6	361,2
Oviston	30° 42'	25° 46'	1294	0,0	5	39,2	69,7	68,1	64,3	30,1	4,4	2,0	6,7	3,8	44,0	22,9	35,7	396,1
Klipfontein (x)	30° 40'	25° 45'	1250	0,0	22	53,6	56,9	72,9	36,1	23,6	6,9	6,4	12,7	21,1	29,0	52,1	44,5	415,8
Hendrik Verwoerd Dam	30° 37'	25° 30'	1321	0,0	5	38,5	45,3	54,7	47,5	28,6	5,6	5,1	4,5	6,7	35,8	22,2	23,3	306,5
Norvalspont	30° 38'	25° 28'	1219	1,0	35	41,1	55,8	62,9	34,9	28,3	5,4	8,5	10,2	17,6	25,9	37,2	42,4	370,2
Tweefontein	30° 34'	25° 25'	1250	2,5	37	39,6	59,0	67,4	38,4	25,9	6,3	7,4	11,4	13,6	25,8	40,4	41,4	376,6
Rietbult	30° 30'	25° 13'	1204	1,0	25	60,2	62,2	66,0	33,8	23,9	14,5	7,4	9,4	13,7	22,8	29,8	38,9	382,3
Olivewood	30° 24'	25° 00'	1173	4,5	41	33,3	55,9	65,3	37,2	24,7	5,8	7,5	11,5	13,9	23,3	31,5	33,5	343,4
Kareepoort	30° 16'	25° 06'	1341	7,0	45	42,8	56,8	74,0	35,0	26,4	6,8	15,6	12,3	16,8	23,7	38,8	39,4	386,4
Nooitgedacht	30° 11'	24° 55'	1227	5,5	28	38,5	46,3	58,4	36,0	25,1	3,1	7,4	11,2	15,7	24,9	35,7	35,9	338,2
Kalkfontein	30° 03'	24° 56'	1234	10,0	7	22,2	77,0	70,9	25,4	14,2	3,8	3,8	5,3	14,2	27,7	34,0	22,4	320,9
Blouboshoek	30° 01'	24° 56'	1270	11,0	10	48,0	42,2	60,5	20,8	19,6	6,9	5,6	9,4	15,8	33,0	41,4	42,9	346,1
Boshoffsdam	29° 57'	24° 52'	1250	9,0	15	37,3	52,0	79,9	52,4	26,0	7,0	9,9	13,8	14,4	28,2	35,2	41,4	397,5

TABLE 2 - (continued)

Station	S. lat.	E. long.	Alt. (m)	Distance from river-bed (km)	Period (years)	Average rainfall (mm) Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Tevredenheid	29° 57'	24° 49'	1227	6,0	51	38,9	53,0	70,9	37,2	22,8	7,2	7,9	11,7	13,2	26,1	37,4	36,1	362,4
Boschrand	29° 55'	24° 49'	1219	8,0	17	37,6	39,4	79,0	32,8	21,1	5,6	6,1	10,7	15,2	24,1	45,0	40,1	356,7
Petrusville	30° 05'	24° 40'	1212	11,0	61	44,8	50,6	65,8	36,3	23,9	7,0	7,6	10,1	17,9	25,9	32,5	36,2	358,6
P.K. le Roux Dam	30° 00'	24° 44'	1207	0,0	5	37,5	48,5	55,3	82,3	21,1	2,6	10,0	1,0	2,5	32,4	19,3	27,4	339,9
Vissersdrift	29° 57'	24° 41'	1158	4,0	35	33,0	50,3	69,9	32,0	20,6	3,8	5,6	9,9	16,5	22,9	32,0	34,5	331,0
Bleskop	29° 50'	24° 36'	1109	5,0	30	35,9	54,1	54,5	38,1	20,4	4,9	6,8	10,5	11,3	27,8	33,0	35,6	332,9
Bakovenspan	29° 48'	24° 19'	1097	9,0	24	17,3	40,9	44,4	28,9	13,8	1,7	5,0	6,8	10,3	20,5	33,6	23,6	246,8
Zoutpansdrift	29° 43'	24° 22'	1112	0,0	22	26,4	49,3	46,7	36,8	19,8	2,8	6,4	9,4	13,2	26,2	40,1	31,2	308,3
Thorndale	29° 42'	24° 21'	1090	1,0	14	35,8	49,0	77,5	21,3	14,5	2,0	4,8	11,2	12,5	11,9	23,1	29,7	293,3
Oranjerivier - station	29° 38'	24° 13'	1073	2,5	73	34,3	41,5	55,0	25,0	16,2	6,2	4,5	6,6	10,8	16,4	27,2	27,0	270,7
Hopetown - prison	29° 37'	24° 05'	1098	2,0	81	40,7	46,1	62,0	31,9	20,3	6,8	5,9	7,5	11,6	19,4	31,2	29,6	313,0
Hopetown - old bridge	29° 34'	24° 05'	1067	0,0	7	42,4	42,2	57,7	27,2	22,6	7,1	4,6	10,9	10,7	23,6	29,2	14,2	292,4
Eskdale	29° 27'	24° 00'	1097	2,0	14	55,6	42,4	66,3	37,6	17,0	13,7	4,6	3,8	9,7	18,0	26,7	38,4	333,8
Torquay	29° 16'	23° 50'	1067	0,5	5	33,1	49,2	48,1	16,6	30,3	9,5	2,8	9,1	7,0	13,5	37,5	38,0	294,7
Douglas - prison	29° 03'	23° 46'	1030	10,0	70	46,3	60,0	69,3	29,1	16,7	4,3	3,7	6,8	10,4	18,5	26,9	33,7	325,7
Bucklands	29° 04'	23° 40'	1006	2,0	22	42,7	48,8	69,1	18,8	12,2	2,0	2,5	7,1	11,2	15,5	30,5	32,0	292,4

Stations marked with (x) are now beneath the waters of the Hendrik Verwoerd Dam

An insight into the rainfall pattern of the area in relation to the whole of southern Africa can be acquired from Jackson (1961). These maps show mean monthly rainfall and monthly percentage of mean annual rainfall. According to data from the Weather Bureau (1965a, b) there is a slight diurnal variation in precipitation in the Upper Orange River area. The maximum seems to fall in the afternoon and early evening, the minimum in the late morning. In the Upper Orange River area the rainfall usually comes in the form of thunderstorms which means that the precipitation is of great intensity but lasts for only short periods of time. This is also indicated by the frequency of days with thunder. In the east near Sterkspruit an average annual number of 70 days with thunder occur and in the west near Griquatown this figure is 40 (Weather Bureau, 1965a). In the Upper Orange River area, and indeed over the greater part of South Africa it frequently happens that though the rain can be seen falling in streaks (virga), it evaporates before reaching the ground, due to the hot dry surface air.

Associated with thunderstorms, precipitation in the form of hail is not rare in the Upper Orange River area. A generalized map of the Weather Bureau (1965a) shows that the figure for the average number of days per annum with hail, decreases from 5 in the Sterkspruit area to 1 in the Griquatown area. Hail occurs most frequently in November i.e. in the late spring.

Few reliable data are available on the frequency and intensity of snowfall. Although it can occur rarely over the entire Upper Orange River area, it is most frequent in the higher parts, particularly in the area around Sterkspruit during the end of June. On the mountains of the southeastern escarpment (Drakensberg) snow falls on an average eight times per year (Weather Bureau, 1965a).

2.2.8 Climatological classifications

Several climatological maps of southern Africa have been produced according to different criteria for classification.

Köppen & Geiger (1936) used precipitation and temperature characteristics for a classification system of the climates of the world in such a way, that the limits and boundaries fitted into known vegetation distribution patterns. The classification of the climates of South Africa according to the Köppen & Geiger system was carried out by Schulze (1947), who used data from 504 stations. On Schulze's map the Upper Orange River area falls mainly in the category BSkw' (steppe climate, cold and dry, with a mean annual temperature below 18 °C, but the mean temperature of the warmest month exceeding 18 °C, dry in winter, rainy season in March and April). Upstream of Sterkspruit the climate is of the class Cwb (warm temperate, rainy climate, with dry winters, mean temperature of the warmest month over 22 °C, of the coldest month below -3 °C, and with at least one month with a mean temperature below 18 °C and eight months with a mean temperature exceeding 1 °C). Between Hopetown and Douglas there is a narrow zone just falling in BWkw' (desert climate, cold and dry, with a mean annual temperature below 18 °C, but the mean temperature of the warmest month exceeding 18 °C, a dry winter and the rainy season during March and April). The lowest part of the Orange River valley falls in the class BShw' (steppe climate, dry and hot with a mean annual temperature over 18 °C, a dry winter with the rainy season during March and April). In the part downstream from Hopetown the boundary between the classes BWkw' and BShw' runs very close and nearly parallel to the river. The distribution of these four climatic types over the Orange River valley is shown diagrammatically in Fig. 16.

Schulze (1947) also classified the climates of South Africa according to the Thornthwaite system (1931). Thornthwaite's system is based on the relationship between precipitation, evaporation and temperature. Schulze (1947) considers Thornthwaite's system to give a good picture of the effectiveness of precipitation when used in a detailed survey of a small area, but a major objection against the system is that it fails to give an adequate picture of seasonal variation. The Upper Orange area falls into three different classes of the Thornthwaite system: East of Aliwal North CB'd (sub-humid warm climate with deficient moisture in all seasons); between Aliwal North and Hopetown DB'd (semi-arid warm steppe climate) and west of Hopetown EB'd (arid warm desert climate) (Schulze, 1947). Thus the Köppen & Geiger and the Thornthwaite systems agree that the border between steppe and desert climates lies near Hopetown, and another major climatic boundary runs not far east of Aliwal North.

Of interest for this survey are three climatic classification systems that are especially developed in regard to vegetation or biocoenoses (Walter & Lieth, 1960; UNESCO-FAO, 1963; Troll & Paffen, 1964) and are discussed below.

In order to be able to compare details in the climates of geographically separated localities Walter & Lieth (1960) used climatic diagrams. Precipitation and temperature values as well as certain extreme values, such as absolute minimum and maximum temperatures, number of days with frost per year and the average daily range in temperature are of considerable importance in the physiology of the plant and are therefore included in the climatic diagram (Fig. 4). Walter & Lieth (cf. Geiger, 1965) emphasize that although the climatic diagrams usually give a good picture of the local climatic situation they are of restricted value in ecological and applied biological studies for the following reasons: Firstly, all recordings are taken under protection from radiation, whereas the plants receive unlimited solar radiation. This influences their water balance, temperature and photosynthesis rate. Secondly, all data are recorded at a level of 1,20 m above the ground in order to avoid disturbances caused by the lowest atmospheric layers. These layers are, however, of

overriding importance for most plants. Thirdly, climatic diagrams give the means over a longer period. Plants are exposed to irregular deviations of the normal pattern, and extremities are usually of major importance.

The Upper Orange River area is crossed by two type boundaries (Walter & Lieth, 1960). Between Aliwal North and Goedemoed runs a boundary, to the East of which the area falls into the regime of type II3a. West of this boundary as far as the neighbourhood of the P.K. le Roux Dam the area falls into type II4a (type II is a tropical or subtropical summer rainfall area; subdivision has not yet been characterized). Downstream from the P.K. le Roux Dam the river enters type II (III)a (arid tropical or subtropical summer rainfall area; subdivision not yet characterized), which extends to Brakrivier near Prieska.

UNESCO-FAO (1963) point out that it is important to use only meteorological data for a bioclimatic map. But these meteorological data must be those that have a definite action on plants, for "of all living entities, plants are the only ones wholly of the climate of their habitat". Ombrothermic diagrams and xerothermic indices are then chosen as criteria in defining the bioclimatic zones. In an ombrothermic diagram, just as in Walter & Lieth's climate diagrams, temperature and precipitation are plotted against each month. The xerothermic index, or index of hot weather drought, is the sum of the monthly indices for the dry months, where a dry month is defined as a month in which the total precipitation (in mm) is equal to or less than twice the mean temperature of the month (in °C). The monthly index denotes the degree of drought of a given dry month and is defined as the number of days in the month which can be deemed dry from the biological point of view. In calculating the monthly index the number of days without rain are used to allow for the character of showers; a day with mist and dew is reckoned as half a dry day, and a day without precipitation and an atmospheric humidity of 40 % or lower is reckoned as a dry day whereas it counts for half a dry day when the humidity equals 100 %. A sliding scale provides for estimation of dry amounts on days with a humidity between 40 % and 100 %. Thus the xerothermic index gives the number of "biologically" dry days during the dry season.

According to this classification system, the Upper Orange River area is covered by three bioclimatic zones (UNESCO-FAO, 1963): From within Lesotho to Norvalspont the river flows through the intermediate temperate tropical zone; from Norvalspont to near the P.K. le Roux Dam it flows through the accentuated temperate tropical zone, and from the P.K. le Roux Dam to Douglas through the attenuated sub-desert zone (Fig. 5).

An intermediate temperate tropical climate is a climate with a dry period lasting between one and eight months coinciding with the period of shortest daylight, with a mean temperature of the coldest month being between 0° and 10 °C, and with a

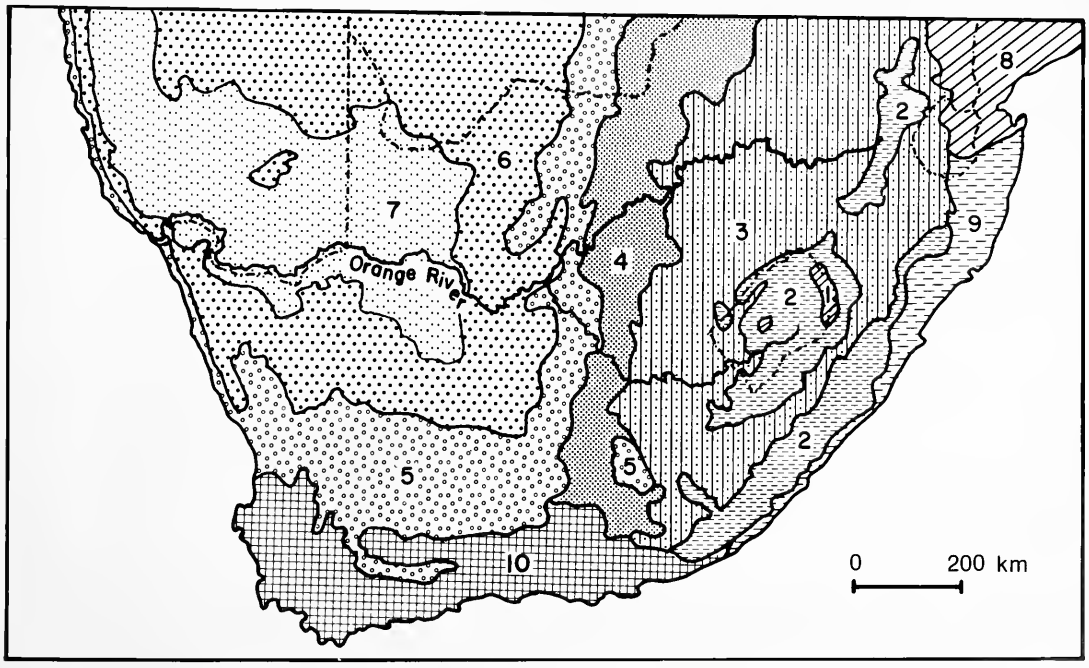


FIG. 5 - The climates of southern Africa. Note the gradient from temperate tropical climate to sub-desert climate in the Upper Orange River area. 1. Cold temperate axeric climate; 2. Sub-axeric and attenuated temperate tropical climate; 3. Intermediate temperate tropical climate; 4. Accentuated temperate tropical climate; 5. Attenuated sub-desert climate; 6. Accentuated sub-desert climate; 7. Desert climate; 8. Warm tropical climates; 9. Warm axeric (sub-equatorial) climates; 10. Mediterranean climates. (Terminology and adapted map from UNESCO-FAO, 1963, with permission)

xerothermic index of between 100 and 150. The accentuated temperate tropical climate differs from the intermediate one in that it has a xerothermic index between 150 and 200 (long dry season). An attenuated sub-desert climate means a climate with a dry period lasting between nine and eleven months and a xerothermic index between 200 and 250.

Based on the premise that most aspects of life show a seasonal rhythm, Troll & Paffen (1964) compiled a seasonal climatic map of the world based on light, radiation, temperature and precipitation. The entire Upper Orange River area falls into zone IV (warm-temperate subtropical zone with mild winters in which the temperature of the coldest month is between 6° and 13 °C). A subdividing boundary runs close to Bethulie. East of this the area falls in type IV4 (dry winter climate with long summer humidity, generally six to nine humid months). West of this boundary as far as the neighbourhood of Griquatown the area falls into type IV3 (steppe climate with short summer humidity and dry winters; less than five humid months).

Thus, it will be noticed that whereas Walter & Lieth (1960) and UNESCO-FAO (1963) draw the boundary between steppe or sub-desert climate and subtropical or temperate tropical climate near the P.K. le Roux Dam, Troll & Paffen (1964) draw it as far east as Bethulie. Walter & Lieth (1960) and UNESCO-FAO (1963) subdivide the subtropical zone into a more arid and a less arid part with a boundary between Norvalspont and Aliwal North.

2.2.9 Mesoclimate and microclimate

Meso-, and particularly micro-climatological, topics are discussed in detail by Geiger (1965) and summarized by Werger (1973b). Meso- and microclimate are of primary importance in the ecology of each individual site. There are very few specific South African data and findings of this nature, none of which deal with the Upper Orange River valley. In South Africa Aitken (1922) did some observations upon the effect of slope exposure near Pietermaritzburg, whereas Schulze (1970) discussed the effect of slope direction on the intensity of noon insolation in Natal. Müller (1970) carried out measurements on temperature, humidity and evaporation in a hilly area covered with grass, bush and karroid communities near Bloemfontein, whereas temperature, humidity, evaporation and light penetration measurements were taken by Van Zinderen Bakker (1971) inside and outside a ravine forest in the northeastern Orange Free State.

An interesting fact about the influence of Australian open semi-desert scrub upon moisture distribution in the soil after a shower, was published by Specht (1958; cf. Walter, 1968). He found that plants direct the water of the rain drops along their surfaces and concentrate it in drops in the vicinity of the main root system, so that the day after the rain the highest moisture content is found in the root zone of the plants and not under exposed surfaces where the rain could fall unhindered. The plants with the largest aerial cover had intercepted the largest quantity of rain water and deposited it in their root zones thus favouring themselves and smaller plants in their shade, making the establishment of plants on bare spots more difficult.

Similar results were obtained in Kenya by Glover *et al.* (1962) in a number of open grassland communities, some of them with scattered trees and thicket clumps. They ascertained a direct relationship between the depth of rain-water penetration into the soil and the height of the plant at each spot, as well as between the sectional area of the wet soil mass beneath each vegetation clump and the sectional area of the clump above ground. This may partly explain the fact observed by Cannon (1924), that in the arid parts of southern Africa, succulents often grow under larger non-succulents.

The considerable topographical differences existing in the Upper Orange River area will be of relatively great importance on the meso- and microclimate and ecology of individual sites. This will have its reflection in the composition and distribution of the plant communities of the area. That these topographical differences have their impact on the mesoclimate of the various localities is shown by the deviating climatological records of stations like Mohaleshoek and P.K. le Roux Dam.

2.3 GEOLOGY

The geological stratification has been discussed in detail by Du Toit (1954) and Haughton (1969), while geological maps have been compiled by Truter & Rossouw (1955) and Coertze & Schifano (1970). Fig. 6 presents a simplified section of this latter map, showing the surface geology of the Upper Orange River area.

The Upper Orange River flows virtually only over strata of the Karoo System, which are packed upon each other practically horizontally. The successively older Series of the Karoo System, the Stormberg Series with basalts, the cave sandstones, Molteno and Red Bed sandstones and shales, the Beaufort and Ecca Series both with sandstones, mudstones and shales, and the Dwyka Series with shales and tillites, surface in sequence at successively lower altitudes away from the Drakensberg. Outcropping dolerite dykes and sills are frequently traversed by the Orange River, particularly in the sector upstream from Hopetown.

Downstream from Hopetown the Upper Orange River has eroded its stream-bed at several localities through amygdaloidal andesitic lavas of the Ventersdorp System (Fig. 6).

Striated surfaces on pre-Karoo deposits and tillite are also found in this area, giving evidence of the Gondwana glacial period (Fig. 7).

In the lower parts of the Upper Orange River, downstream from the P.K. le Roux Dam, red to grey dune sand deposits occur locally. Their age

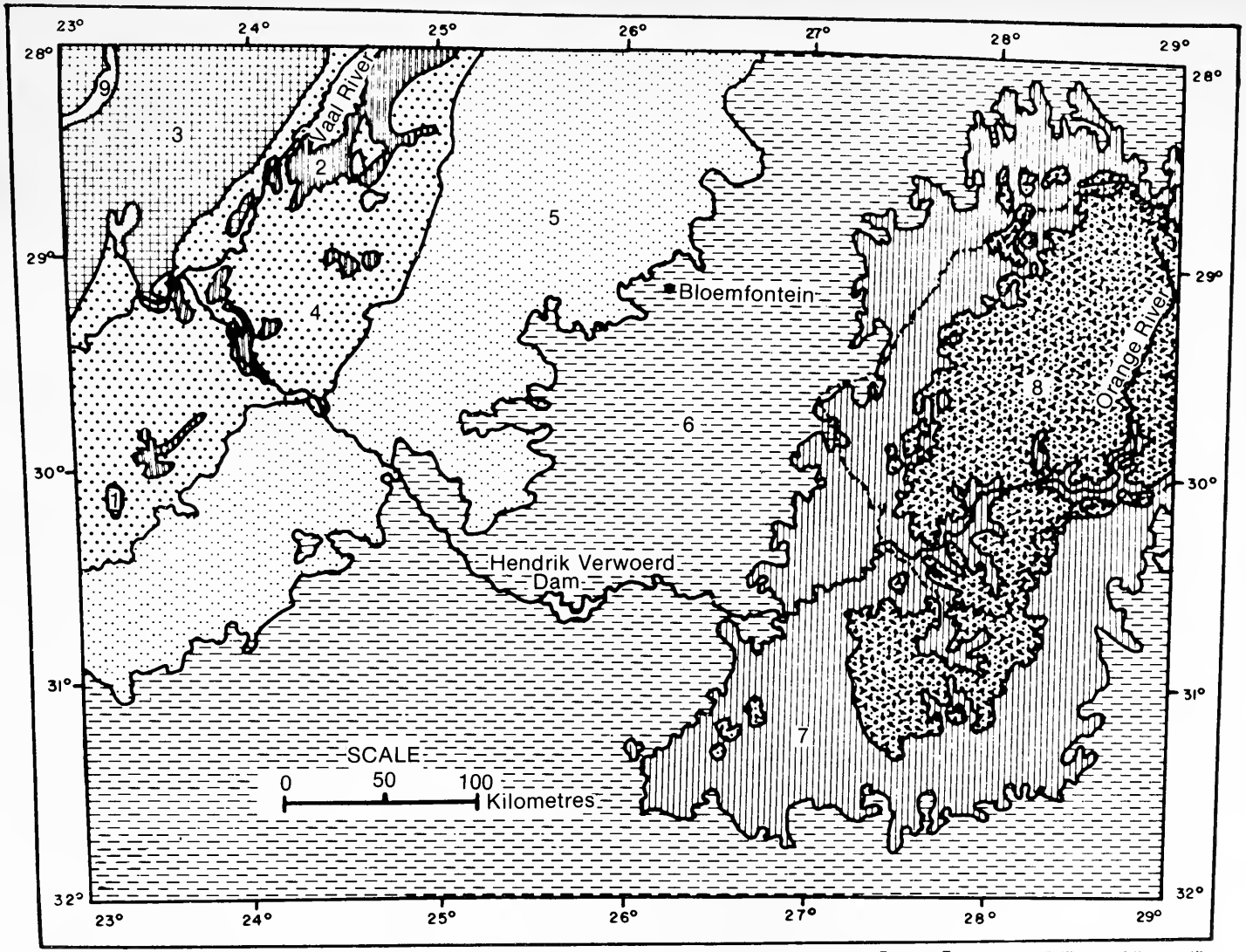


FIG. 6 - Geological map of the Upper Orange River area. 1. Archaean gneiss, etc.; 2. Andesitic lavas of Ventersdorp System (Precambrian); 3. Transvaal System (Precambrian); 4-8 Karoo System; 4. Dwyka Series (Upper Carboniferous to Lower Permian); 6. Beaufort Series (Triassic); 7. Molteno, Red Beds, and Cave Sandstone stages of Stormberg Series (Triassic to Jurassic); 8. Basalts of Drakensberg stage of Stormberg Series (Jurassic); 9. Tertiary to Quaternary deposits (adapted from Coertze & Schifano, 1970,with permission)

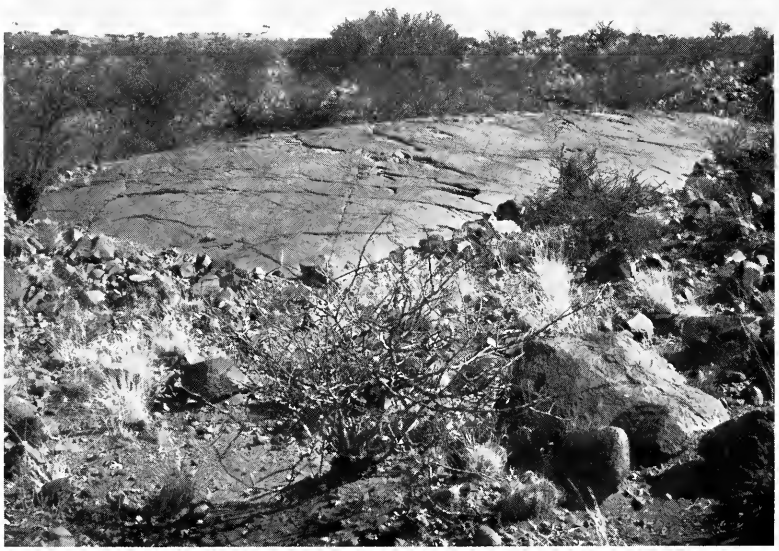


FIG. 7 - Striated bed rock of andesitic lava, Ventersdorp System, near Torquay, bearing engravings of neolithic man. Surrounding vegetation: Melhanio rehmannii-Hermannietum spinosae

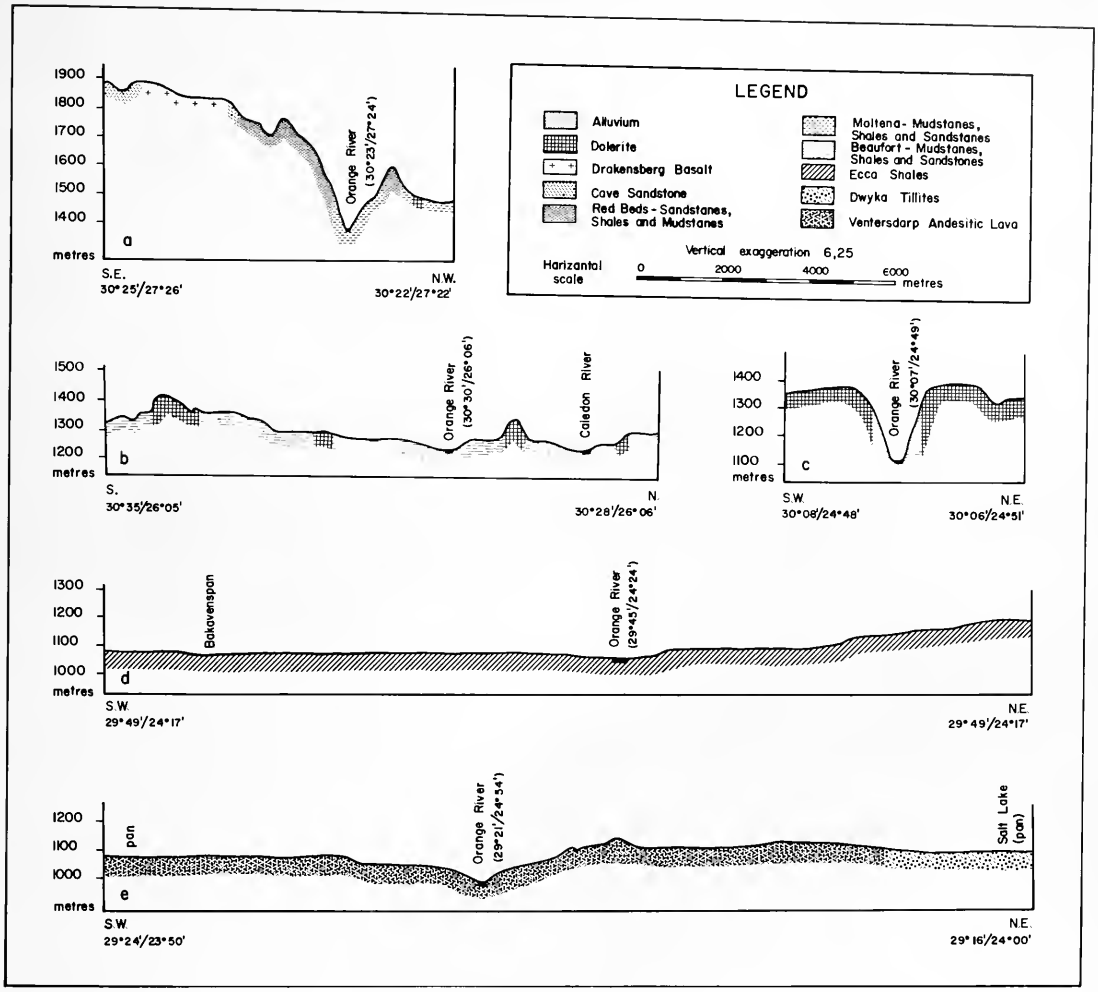
extends back from the Pleistocene well into the Tertiary (Miocene) (Du Toit, 1954). In the same area local calcrete formations also occur frequently, often reaching considerable thicknesses.

Recent alluvial deposits occur virtually along the whole bed of the Upper Orange River in a narrow zone. Some of the these sandy deposits have subsequently been moved by wind action.

2.4 GEOMORPHOLOGY

King (1967) divided southern Africa into some eighteen geomorphic provinces. This division compares reasonably well with Wellington's (1946, 1955) regional physiographic classification. Both classifications first distinguish between the interior plateau and the area marginal to the plateau. The Upper Orange River area falls completely into the interior plateau, but is subdivided into two classes, the South African Highveld (Wellington, 1946, 1955) or Highveld (King, 1967) and the Cape Middleveld (Wellington, 1946, 1955; King, 1967), with a common border zone crossing the Orange River in a NE-SW direction between the P.K. le Roux Dam and Hopetown.

The Highveld lies between 1 200 and 1 800 m above sea level and consists largely of extremely broad valley forms incised below the smooth surface of the "African Cycle", which can still be traced upon the major ridges (King, 1962, 1967). The gradual border between two subtypes of the Highveld, the Basuto Highlands and the Highveld (Karoo formation) lies where the Orange River enters the Republic of South Africa. Relief is rugged here, but gradually changes towards the west into a wider plain with innumerable "koppies" and mesas capped by sheets of dolerite. These outcrops are mainly of the Molteno stage of the Stormberg Series and of the stages of the Beaufort Series. In the Herschel District the Orange River has incised a steep and deep valley into the surface of Red Bed and Molteno strata (Figs 8a and 9), but from Aliwal North to downstream from Colesberg the narrow stream-bed of the river lies on a wide pediplain, a feature that is so typical of South Africa (Fair, 1948; King, 1967). Near Colesberg, for instance, this pediplain is in the form of a great trough, attaining a width of 50 km (Wellington, 1928). In the entire section where the Orange River flows over the nearly horizontal strata of the Red Bed and Molteno stages and the Beaufort Series, the landscape shows many platforms and pseudoterraces, due to weathering of these horizontal strata. Narrow alluvial terraces locally occur along the Orange River over this whole stretch, at about 10 to 30 m above the river-bed (Wellington, 1955). Locally the valley is narrow where it crosses through a dolerite dyke, as near Aliwal North, or a dolerite-capped mesa, as near Goedemoed (Figs 8b and 41). The majority of the transgressive dolerite intrusions have an inclination of between 15° and 50°. Their outcrops thus produce chains of hills, that are marked landscape features over long distances. Sometimes, when the sedimentary layers have eroded away from a large regularly undulating dolerite sheet, such a chain forms a circle (Du Toit, 1954). The typical sphaeroidal weathering (Fig. 10) along the joints of the dolerite caps of the "koppies" and mesas sometimes causes a columnar structure (Fig. 50), and the slopes are always covered with round dolerite boulders of different sizes, which are covered with a brown oxidized layer. The sills and dykes have a strong impact on the movements of underground water (Du Toit, 1954; Haughton, 1969), thus directly influencing erosion, vegetation and the settlement of farmers. Smaller remnants of dolerite dykes and differences in hardness in the Molteno and Beaufort deposits cause small local cascades and rapids in the stream-bed of the



'FIG. 8 - Transverse sections through Upper Orange River valley. The hatchings indicate the surface geology only and not the subterranean disposition of the strata

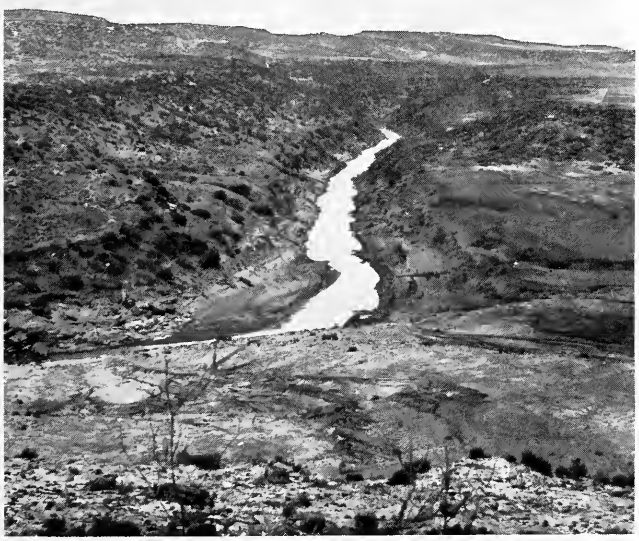


FIG. 9 - Steep-sided valley of the Upper Orange River near Sterkspruit. Note severe erosion in partly overgrazed and partly ploughed land in foreground. Vegetation represents mainly communities of Indigofero spinescentis-Rhoion erosae. No riverine forest occurs along this part of the Orange River

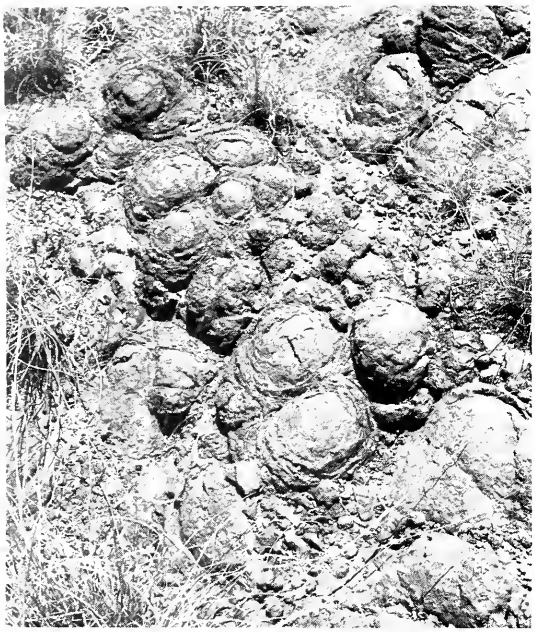


FIG. 10 - Typical sphaeroidal weathering of dolerite

Orange River in the entire Highveld region (Wellington, 1955).

Between Colesberg and the P.K. le Roux Dam the valley of the Orange River is again deep and steep, carved into the dolerite-capped Beaufort deposits (Figs 8c and 46).

In the Highveld region, clayey surfaces on shale and dolerite outcrops alternate with sandy areas where sandstones prevail. Near the western boundary of the region surfaces of wind-blown sands occur.

At the P.K. le Roux Dam the Orange River enters the Cape Middleveld, dominated by what King calls the "Post-African Cycle" of erosion. This cycle extends in a narrow trough, sunk well below the Highveld surface and running up the Orange River as far as its junction with the Caledon (King, 1962, 1967).

The Cape Middleveld lies mainly between 600 and 1 200 m, and the Upper Orange River area falls in the southern subregion of this geomorphic province (Wellington, 1946, 1955). The area is mainly covered with Ecca and Dwyka beds and has the form of an extensive flat plain, only here and there interrupted by dolerite-capped koppies and small mesas. The Dwyka tillite leaves characteristic "pebble pavements" on the surface, after weathering. Particularly between the P.K. le Roux Dam and Hopetown the bed of the Orange River lies upon a flat plain (Figs 8d, 52, 53, 60 and 61). Between Hopetown and Douglas the river has carved a somewhat deeper valley with convex sides into the Ventersdorp lavas (Figs 8e and 55).

Calcrete banks of considerable thickness are widespread over the entire area of the Cape Middleveld and numerous salt and calcrete pans occur in the area (Fig. 11).

2.5 SOILS

In 1962 Van der Merwe published his second revised general classification of soil groups of South Africa. A simplified part of this map, covering the Upper Orange River area, is shown in Fig. 12. In Fig. 16 d'Hoore's (1963) map, which is largely based on Van der Merwe (1962), was used. A summary of Van der Merwe's account on the soils in the Upper Orange River area is provided by Werger (1973b).

For the Upper Orange River catchment area upstream from the Hendrik Verwoerd Dam soils are presently being mapped on a scale of 1:50 000 by H.J. von M. Harmse of Potchefstroom University. The soils of the Herschel District have been mapped separately by Aircraft Operating Company (1967). Eleven series belonging to seven

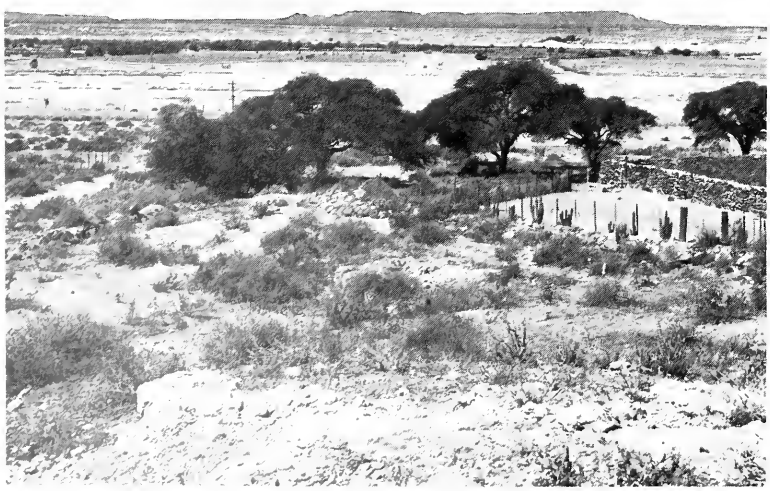


FIG. 11 - Salt Pan between Hopetown and Douglas. Trees are mainly *Acacia erioloba* and shrubs mainly *Hertia pallens* and *Psilocaulon absimile*. In foreground much calcrete

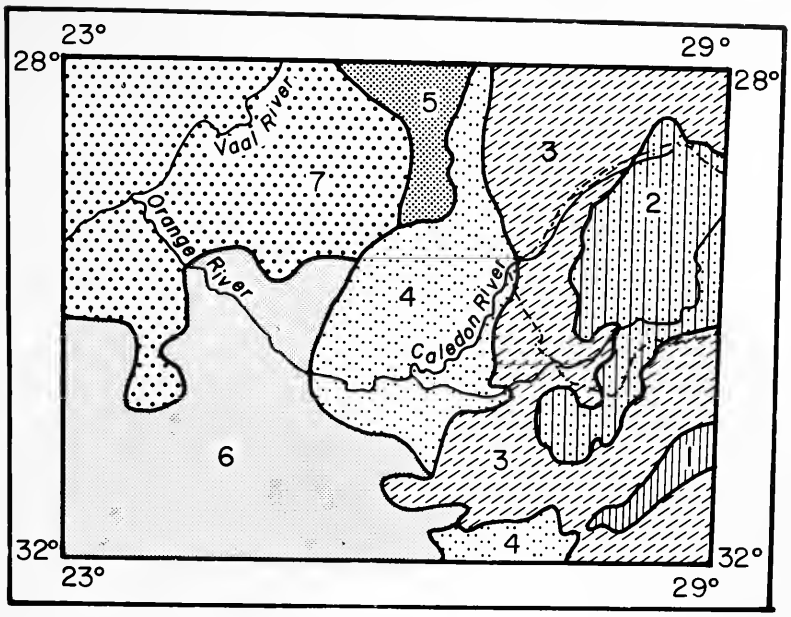


FIG. 12 - Soils map of the Upper Orange River area. 1. Yellow ferrallitic soils; 2. Drakensberg black clay soils (lithosolic) and basalt; 3. Highveld Prairie soils; 4. Solonetzic soils; 5. Aeolian sandy soils; 6. Desert soils (mainly lithosolic); 7. Kalahari sand on calcrete (adapted from Van der Merwe, 1962, with permission)

forms have been distinguished.

In the area, where the Orange River flows over Molteno and Red Bed strata, the soils fall into the subgroup Highveld Prairie Soils of the Gley-like Podzolic Soils group, according to Van der Merwe (1962) (Fig. 12). This subgroup is called Highveld pseudopodzolic soils by d'Hoore (1963). These soils are mainly residual, although on the steeper surfaces some mixing with colluvial material has taken place. Surface (sheet) erosion and gully erosion, which are largely due to poor grazing management and overstocking, are fairly severe in this part of the catchment area, particularly in the Herschel District.

Very frequent in this part of the Upper Orange River area are the lithosols. Particularly on the steeper slopes, but also locally on the plateau, soils are very shallow and stony, with gravel and boulders in a wide range of sizes.

West of the Prairie soils area on the Beaufort deposits as far as the vicinity of Colesberg, the Solonetzic group of soils occurs (Van der Merwe, 1962; d'Hoore, 1963) (Fig. 12).

Sheet and gully erosion are severe in this area while wind erosion as evidenced by the dust-storms which frequently occur in the area, also plays an important role. Again, this erosion is mainly due to poor grazing management and overstocking (Figs 13 and 14).

Sandy loam soils derived from dolerite and containing many boulders and gravel, are abundant. The dolerite derived soils are mainly colluvial and situated on the slopes of ridges, koppies or mesas (Van der Merwe, 1962).

Along drainage lines towards the foot of the higher lying areas, dark clayey soils are found in which both surface and internal drainage are poor. Lithosols occur locally in this area, too.

The soils in the Upper Orange River area between Colesberg and Hopetown, underlain by Beaufort and Ecca deposits, fall into Van der Merwe's (1962) category of Desert Soils (Fig. 12). On the soils map by d'Hoore (1963) a subdivision, crossing the Orange River in the vicinity of Skurwekop, is made. The soils in the area between Colesberg and the vicinity of Skurwekop are classified as lithosols and semi-desert soils, and those between Skurwekop and Hopetown as lithosols, semi-desert soils and saline, alkali and saline-alkali soils.

Because of low rainfall and more open vegetation in the zone of this soil group, these soils are deficient in organic material and chemical decomposition is less important in their formation. Although the soils are mainly of the lithosolic type, and there is usually not much horizon development in the other soils of this zone, some well developed soil profiles can be found. Hard calcrete pans and occasional salt-pans occur frequently in the area (solonchaks). On mountain ridges a light brown sandy soil mixed with rock fragments occurs locally, and on dolerite hills the soil is very shallow or is found only in fissures between large boulders. Small alluvial deposits sometimes occur along the rivers and drainage lines in this area as well as in the other zones of the Upper Orange River. Some wind-blown deposits also occur locally.

A more detailed map of the soils in the Upper Orange River area and part of the Middle Orange River area downstream from the P.K. le Roux Dam, was drawn by Van Rooyen & Dowsey (1961). The irrigable lands in this area down as far as Hopetown, were mapped subsequently in detail by Bruwer *et al.* (1961) and by Pellisier (1971). Van Rooyen & Dowsey's map (1961) shows that the soils in the sector between the P.K. le Roux Dam and Hopetown are mainly lithosols of different types. Patches of fine red sand of aeolian origin

FIG. 13 - Severe soil erosion in Solonetzic soils near Aliwal North. In background Rhoo-Aloetum ferocis

FIG. 14 - Pillar of soil carries a large rock in severely eroded solonetzic area near Aliwal North

also occur. These sands are generally referred to as Kalahari sands. Near the Orange River some patches of yellowish-brown, fine to medium, wind-blown sand are found, and the authors consider them to have originated from Orange River deposits. Small patches of grey to brown and red-brown clay to clay-loam of four different series occur in this area too. Calcrete concretions occur in all these soil types, in the alluvial and aeolian types merely in the lower horizons and in the colluvial types throughout the whole profile. Calcrete banks are also frequent.

In the section of its course between Hopetown and the Orange-Vaal confluence, where the Orange River flows over Dwyka shales, tillite and Ventersdorp lava, the soils fall into Van der Merwe's (1962) group of Kalahari Soils, subgroup Kalahari sand-on-lime which includes areas where calcrete shows on the surface (Fig. 12).

The typical soils of this subgroup are of an aeolian origin, namely Kalahari sand. In the Upper Orange River area these soils are shallow in comparison with the Kalahari proper. The characteristic horizons of these soils are sand and calcrete, but they do not always occur together due to factors such as erosion, lack of sand deposits, lime deficit in the underlying rock, or removal of the surface sandy horizon (Van der Merwe, 1962).

On the rocky outcrops in this area that are not covered by sand, virtually no soil has been formed. The slopes are stone-strewn and the vegetation roots in sandy and loamy fillings of pockets, cracks and fissures in the rock or between the boulders.

In the shallow pans in the area solonchaks are frequent (Van der Merwe, 1962) (Fig. 11).

2.6 VEGETATION

Apart from the riverine forest, woodland and scrub, the vegetation of the Upper Orange River area can at first glance be divided into three major physiognomic categories: the grasslands in the area east of Aliwal North, the xerophytic dwarf shrub types covering the remaining part of the area and, in the

section between Hopetown and Douglas, an open savanna with trees and shrubs which nearly reaches the valley from the north. In describing the vegetation of South Africa most authors have distinguished these main categories.

In his still valuable description of the vegetation of "Das Kapland", Marloth (1908) subdivides the vegetation of the Upper Orange River area into three parts: east of Bethulie the short grasslands of the Highveld, with *Themeda triandra* the dominant species; between Bethulie and Petrusville the eastern part of the "Karroide Hochland"; and northwest of Petrusville the *Acacia*-steppes of the West Griqualand part of the Kalahari. The eastern part of the karroid Highlands is covered with dwarf shrubs, of which Compositae comprise up to 90 per cent of the species. *Pentzia globosa* and *Chrysocoma tenuifolia* are dominant. Amongst other important species Marloth (1908) mentions *Gazania* sp., *Hermannia spinosa, Aptosimum depressum, Gnidia polycephala* and *Lycium* sp.

Bews (1916) gives a very general account of the vegetation of South Africa in strong Clementsian terminology. He also recognizes a grassland, a xerophytic dwarf shrub land and a savanna. Although he regards the eastern grassland and the dwarf shrub steppe of the Great Karoo as formations in the sense of true successional stages, he considers the type of dwarf shrub vegetation in the Upper Orange River area, to which he refers as "Compositae Veld", as "transitional between Karoo and Grassland". His description of this vegetation type is largely based on Marloth (1908). In a private communication, he also described the woody riverine vegetation as it occurs near Upington. Early botanists and travellers often refer to this *Acacia karroo* dominated riverine zone, probably because it is so conspicuous, being the only real tree growth in an extensive arid area (e.g. Burchell, 1822 - 1824; Brunnthaler, 1911).

In 1925 Bews gave a floristic account of South African vegetation types, emphasizing the relation between growth form, distribution and habitat. Whereas plant succession is towards the mesophytic, the evolution of plant growth forms has proceeded towards the xerophytic, according to Bews (1925) so that ecological evolution has more or less reversed the order of plant succession. In the progress from grassland through Compositae veld to Karoo, the plants become increasingly xerophytic. In grassland a growth-form occurs, which he calls "associated plants of the grass-veld". This form is adapted to open grassland conditions and has either a vernal or an aestival and autumnal aspect, the latter being more shrubby. A very great number of the plants belonging to the form with vernal aspect are geophytes or show a tendency to form subterrestrial storage organs. In the grassland proper they are abundant in the early stages of succession but tend to disappear in the later stages since grass itself has a growth-form that is more suitable for climax plant growth in the grassland climatic zone. In the "Compositae Veld" these growth-forms "associated with grassveld" become more prominent, particularly those with autumnal aspect, and in Karoo vegetation they are dominant. The Karoo vegetation shows no succession; "it stops, where it begins", due to climatic factors. These plants of the Karoo, like the xerophytic Compositae, succulents and annuals must be regarded as a recent development (Bews, 1925).

In spite of their general titles Compton's articles (1929a, b) deal only with the winter rainfall Karoo in the southwestern Cape. A life-form spectrum of this part of the Karoo is compared with those from Death Valley in the U.S.A., the Libyan Desert and Aden showing considerable differences.

Pole Evans (1936) maps the vegetation of South Africa into twelve types, being subdivisions of the four main types, namely: forest, parkland, grassland and desert shrub. Near Aliwal North the boundary between the types "short grass" and "desert shrub" of the main type "grassland" crosses the Orange River. The type "thorn country" of the main type "parkland" never approaches the Orange River in its upper part, according to Pole Evans's map. The dominant grass of the "short grass" is a dwarf form of *Themeda triandra*, and a number of other grass species are frequent. The uniformity in the general appearance of the vegetation of the type called "desert shrub" is remarkable. The vegetation consists preponderantly of xerophytic, narrowly leaved shrubs and shrublets of fairly uniform height, which are always widely spaced in otherwise nearly bare soil. Pole Evans (1936) mentions as common species *Pentzia incana, Pentzia globosa, Lycium arenicolum, Chrysocoma tenuifolia, Euphorbia mauritanica, Salsola aphylla, Rhigozum trichotomum, Rhigozum obovatum, Phaeoptilum spinosum*, and others.

Adamson (1938) divides the vegetation of South Africa into five main types: sclerophyll, forest, savanna, grassland and semi-desert vegetation. His map shows grassland east of Aliwal North, Karoo-bush between Aliwal North and Petrusville, and *Gnidia* community from Petrusville to the neighbourhood of Douglas, where this type verges upon bush savanna. Karoo-bush and *Gnidia* community are subdivisions of the arid bush type of the semi-desert vegetation. The vegetation in the grassland zone of the Upper Orange River belongs to what Adamson calls the dry grassland community, with *Eragrostis, Sporobolus* and *Aristida* species as dominants, although *Themeda* can be dominant locally. *Chrysocoma, Pentzia, Selago* and others are abundant in the driest places according to Adamson (1938).

The arid-bush type communities consist largely of small xerophytic shrubs, of which many belong to the Compositae, whereas succulents are not very common, as opposed to the succulent-bush type communities of the Great and Little Karoo. In the Karoo-bush community *Chrysocoma tenuifolia* and *Pentzia* spp. are by far the commonest. Where salts are concentrated in the top soil, species of *Psilocaulon, Lycium* and others occur. According to Adamson (1938), *Pentzia* and annual grasses can also be abundant in the *Gnidia polycephala*

community in which this species is dominant, in the area between Petrusville and Hopetown. This community grows on deeper soils than the previous one. Near Douglas several communities of the bush-savanna type, such as the *Acacia erioloba* savanna and the *Acacia* bush, reach the Orange River valley.

A fairly general map of the vegetation of South Africa was prepared by Codd (1952), on which the area east of Aliwal North is indicated as intermediate grassland, the area between Aliwal North and the P.K. le Roux Dam as transitional Karoo, and the area downstream from the P.K. le Roux Dam as Karoo. This map served as a basis for the Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale (A.E.T.F.A.T.) map of the vegetation of Africa south of the tropic of cancer (Keay, 1958).

A most useful general account on the vegetation of South Africa is given by Acocks (1953), who distinguishes seven natural main types, four types derived from these, 70 veld types and many variations and subtypes. A simplified modification based on the map by Acocks (1953) was constructed by Edwards (1970) and is given in Fig. 15. Acocks (1953) based his veld types both on floristic composition and practical utilization, defining them as "a unit of vegetation whose range of variation is small enough to permit the whole of it to have the same farming potentialities". Thus, Acocks's classification of veld types provides a suitable basis for land use planning on a regional scale as well as for the planning of ecological studies (Grunow & Morris, 1969) and for vegetation conservation policy (Edwards & Werger, 1972). The Upper Orange River area comprises altogether ten veld types, of which six actually reach the river-bed. These ten veld types belong to four natural and derived main types and their distribution is given in Table 3.

The portion of the sandy *Cymbopogon-Themeda* Veld in the Upper Orange River area belongs to the southern variation. Of this moderately dense, rather short grassveld Acocks (1953) lists as general species: *Themeda triandra, Setaria flabellata, Microchloa caffra, Elionurus argenteus, Heteropogon contortus, Eragrostis chloromelas, E. racemosa, E. capensis*, and many others. Patches of *Pentzia globosa, Felicia muricata* and *F. filifolia* indicate the Karoo invasion in this veld type on eroded places. The *Themeda-Festuca* Alpine Veld, which approaches the Upper Orange River from the east near Mayaputi, is a dense, short grassveld dominated by *Themeda triandra.* Other grass species, such as *Elionurus argenteus, Heteropogon contortus, Eragrostis racemosa, E. capensis, E. curvula* and many others are also common. Temperate grasses, like *Festuca costata, F. scabra, F. caprina, Merxmuellera disticha, Helictotrichon longifolium, Koeleria cristata*, etc. are typical of this veld type. In sheltered ravines a scrub forest relict occurs for which Acocks (1953) lists amongst others the following species: *Leucosidea sericea, Buddleja salviifolia, Rhamus prinoides, Myrsine africana, Erica caffra, Clutia pulchella, Olea africana* and *Celtis africana.*

The southern variation of the dry *Cymbopogon-Themeda* Veld occurs in the Upper Orange River area. According to Acocks this variation had formerly a much wider distribution, covering virtually the entire area of the present False Upper Karoo. Due to bad grazing systems, overstocking and trampling, this grassveld has been damaged so much that it was replaced by the inferior karroid vegetation reducing the grazing capacity of the veld and favouring erosion (Acocks, 1953, 1964, 1966a). Species of general occurrence in this veld type include *Themeda triandra, Tragus koelerioides, Eragrostis chloromelas, E. lehmanniana, E. obtusa, Digitaria argyrograpta, Cymbopogon plurinodis, Helichrysum dregeanum, Sporobolus fimbriatus, Cyperus usitatus, Aristida congesta, A. adscensionis, A. diffusa* var. *burkei*, and many others (Acocks, 1953). The western boundary of these grasslands coincides more or less with that of the pseudopodzolic Highveld soils, as can be seen in Fig. 16. The boundary between the Stormberg and Beaufort Series and the transitional zone between the warm temperate rainy climate and the arid steppe climate also correspond to a certain extent with this boundary between grasslands and False Karoo (Fig. 16).

Over a long stretch, from Aliwal North to the P.K. le Roux Dam, the veld along the Upper

TABLE 3 - Veld types in the Upper Orange River area (Acocks's veld type number in brackets)

Main type	Veld type	Locality in Upper Orange River area
Pure Grassveld	Sandy *Cymbopogon-Themeda* Veld (48)	Upstream from Sterkspruit vicinity
	Themeda-Festuca Alpine Veld (58)	Approaching the Upper Orange River valley near Mayaputi
	Dry *Cymbopogon-Themeda* Veld (50)	In narrow zone upstream from Aliwal North
False Karoo	False Upper Karoo (36)	From a few km upstream from Aliwal North downstream to P.K. le Roux Dam vicinity
	False Arid Karoo (35)	as False Orange River Broken Veld but outside valley trough
	False Orange River Broken Veld (40)	In Upper Orange River valley from P.K. le Roux Dam vicinity downstream to Salt Lake Pan vicinity
Karoo and Karroid Bushveld	Central Upper Karoo (27)	In narrow zone near P.K. le Roux Dam
	Orange River Broken Veld (32)	Downstream from Salt Lake Pan vicinity
Tropical Bush and Savanna	Kalahari Thornveld (16)	In small patch north of Hopetown
	Kalahari Thornveld invaded by Karoo (17)	In small patch near Salt Lake Pan

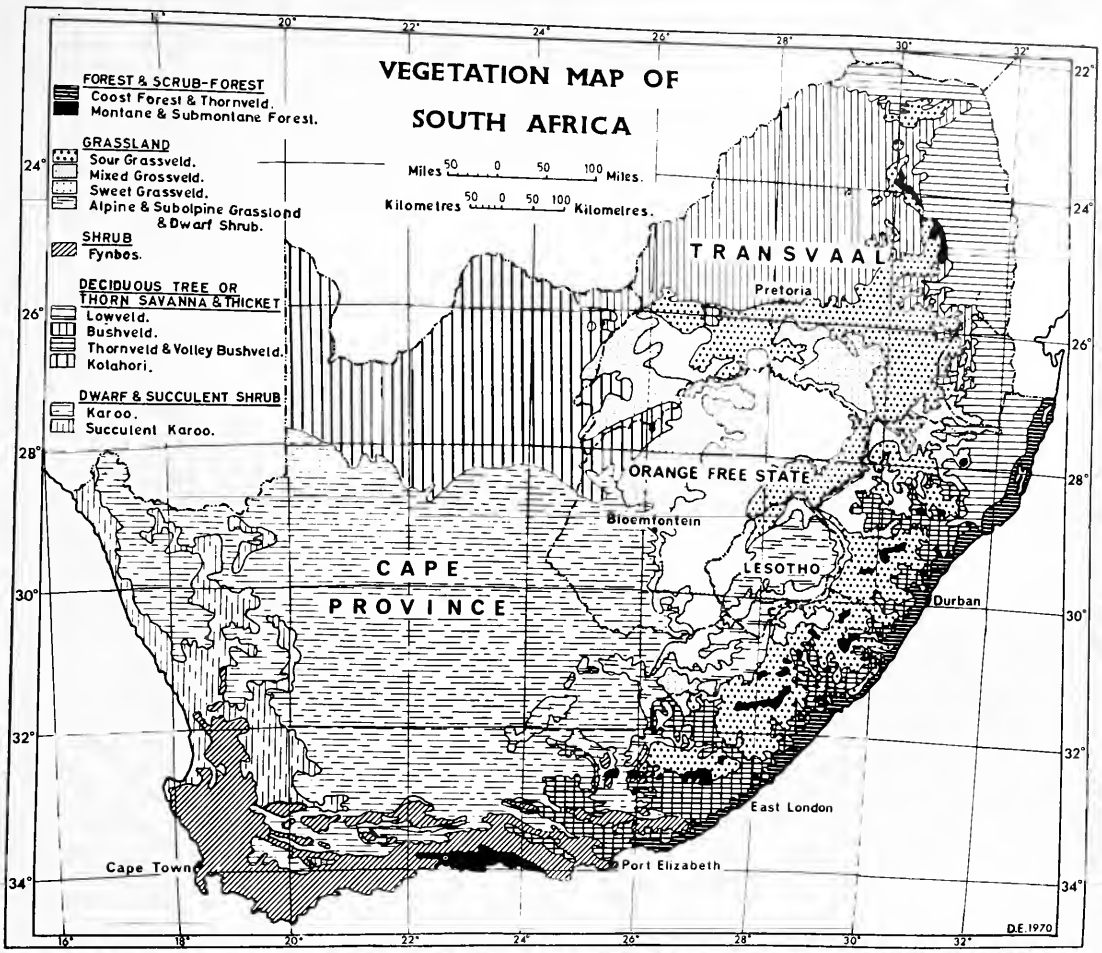


FIG. 15 - Generalized vegetation map of South Africa showing the main floristic-physiognomic types (after Edwards, 1970, with permission)

Orange River comprises a vegetation type that Acocks calls the False Upper Karoo ("false" because it was originally grassveld) (see also notes by early travellers below). "The development of this veld type constitutes the most spectacular of all changes in the vegetation of South Africa. The conversion of 20 000 square miles (50 000 km²) of grassveld into eroded Karoo can only be regarded as a national disaster" (Acocks, 1953). Floristically the composition of this veld type, particularly of the plains, is similar to the Central Upper Karoo, the only difference being the abundance of inferior grazing grasses such as *Aristida adscensionis, A. congesta* and *Eragrostis lehmanniana* in the False Upper Karoo. The slopes still carry mainly grasses and some shrubs of which particularly *Rhus erosa* is abundant. The dominant species at present is *Chrysocoma tenuifolia*, a Karoo pioneer. According to Acocks, the False Upper Karoo vegetation is inclined to be sparser than the genuine Karoo veld types near the margins with the grassveld because until the grassveld soil has eroded away, the Karoo species have no secure foothold.

Harvester termite activity which is conspicuous in this area can damage the vegetation as severely as the occasionally occurring locust plagues[1].

In the vicinity of the P.K. le Roux Dam, the Central Upper Karoo tapers towards the Orange River between the False Upper Karoo and the False Arid Karoo. This is a genuine Karoo veld type, although grasses like *Eragrostis lehmanniana* and *Aristida congesta* are common. On the extensive dry flood plains *Lycium* spp. and *Rhigozum trichotomum* can be abundant, whereas on the slopes *Rhus undulata* var. *tricrenata* is frequent. The aizoaceous species *Eberlanzia spinosa* can be locally abundant. Common species of this veld type, and to some extent of the False Upper Karoo, include *Eriocephalus pubescens, E. spinescens, Pentzia globosa, P. incana, P. spinescens, Plinthus karooicus, Nenax microphylla, Nestlera minuta, Pegolettia retrofracta, Felicia*

[1] In a personal communication Acocks (cf. Acocks, 1953) has said that he now considers that the False Upper Karoo should be subdivided into a northern and a southern part with the Orange River as boundary. In the northern part the relic species of the original grassveld are still more frequent than in the southern part

muricata, Chrysocoma tenuifolia, Salsola glabrescens, Thesium hystrix, Limeum aethiopicum, Gnidia polycephala, Osteospermum leptolobum, Helichrysum lucilioides, Sutera halimifolia, Asparagus suaveolens, Lessertia pauciflora, Pteronia sordida, Eragrostis obtusa, Aristida adscensionis, Enneapogon desvauxii, Fingerhuthia africana, Sporobolus fimbriatus, and many others (Acocks, 1953). The western boundary of the Central Upper Karoo - False Upper Karoo corresponds largely with the one between the Beaufort and Ecca Series in the Upper Orange River area and with the transitional zone between the Highveld and Cape Middle Veld physiographic areas.

The False Arid Karoo reaches the Orange River in a narrow zone just downstream from the P.K. le Roux Dam. This veld-type was originally Central Upper Karoo, but became so completely invaded by elements of the Arid Karoo, that Acocks (1953) regards it as a separate veld type. Apart from a number of Central Upper Karoo species, the following are important: *Stipagrostis obtusa, S. ciliata, Peliostomum leucorrhizum, Aptosimum marlothii, A. spinescens, Hermannia spinosa, Monechma desertorum, Phaeoptilum spinosum, Monechma incanum*, and others.

Downstream from the narrow False Arid Karoo zone, the False Orange River Broken Veld covers the valley trough as far as the vicinity of Salt Lake Pan. It is rather similar to the eastern variation of the Orange River Broken Veld. Thickets of *Acacia mellifera* subsp. *detinens* and of *Rhigozum trichotomum* occur frequently. *Phaeoptilum spinosum, Boscia albitrunca, Cadaba aphylla* and *Acacia tortilis* subsp. *heteracantha* are common. On ruderal sites *Salsola kali* and *Psilocaulon absimile* can be abundant (Acocks, 1953). In the Upper Orange River area the western boundaries of the False Arid Karoo and the False Orange River Broken Veld and the northern boundaries between these veld types and the Kalahari Thornveld (invaded by Karoo), broadly coincide with the one between the semi-desert and saline soils and the Kalahari sands on calcrete, as well as with the boundary between the steppe and desert climates (Fig. 16).

Further downstream the False Orange River Broken Veld grades imperceptibly into the eastern variation of the Orange River Broken Veld proper i.e. the *Acacia mellifera* subsp. *detinens* Veld. Typical trees and shrubs are *Acacia mellifera* subsp. *detinens, Rhus undulata* var. *tricrenata, Rhigozum obovatum, R. trichotomum, Boscia albitrunca, Cadaba aphylla, Phaeoptilum spinosum, Lycium* spp. and *Grewia flava*. The two typical Orange River Broken Veld/Namaqualand Broken Veld species, *Aloe dichotoma* and *Euphorbia avasmontana* just fail to reach the Upper Orange River valley. Other common species in this veld type are *Barleria rigida, B. lichtensteiniana, Cyphocarpha angustifolia, Hoodia gordonii, Pteronia mucronata, Lasiocorys capensis, Asparagus suaveolens, Limeum aethiopicum, Cleome diandra, Senecio longiflorus, Nestlera minuta, Polygala asbestina, Aptosimum spinescens, A. albomarginatum, Monechma desertorum, Hermannia spinosa, Fagonia sinaica* var. *minutistipula, Cenchrus ciliaris, Cypholepis yemenica, Enneapogon desvauxii, E. scaber*, and several others (Acocks, 1953).

In the section between Hopetown and Douglas on the right-hand side of the river the southern parts of the Kalahari Thornveld, and the Kalahari Thornveld invaded by Karoo, almost reach the Orange River valley. The patch of Kalahari Thornveld occurring north of Hopetown is of the central variation of this savanna veld type. Kalahari grasses like *Stipagrostis obtusa, S. ciliata, Antephora pubescens*, and others, as well as *Themeda triandra*, characterize this variation. Other frequent species include *Eragrostis lehmanniana, Pentzia calcarea, Hermannia comosa, Harpagophytum procumbens, Peliostomum leucorrhizum*, and many others in the ground layer, whereas *Acacia erioloba, A. tortilis* subsp. *heteracantha, A. mellifera* subsp. *detinens, Grewia flava, Ehretia rigida, Asparagus laricinus*, and several others are common amongst the woody emergents (Acocks, 1953).

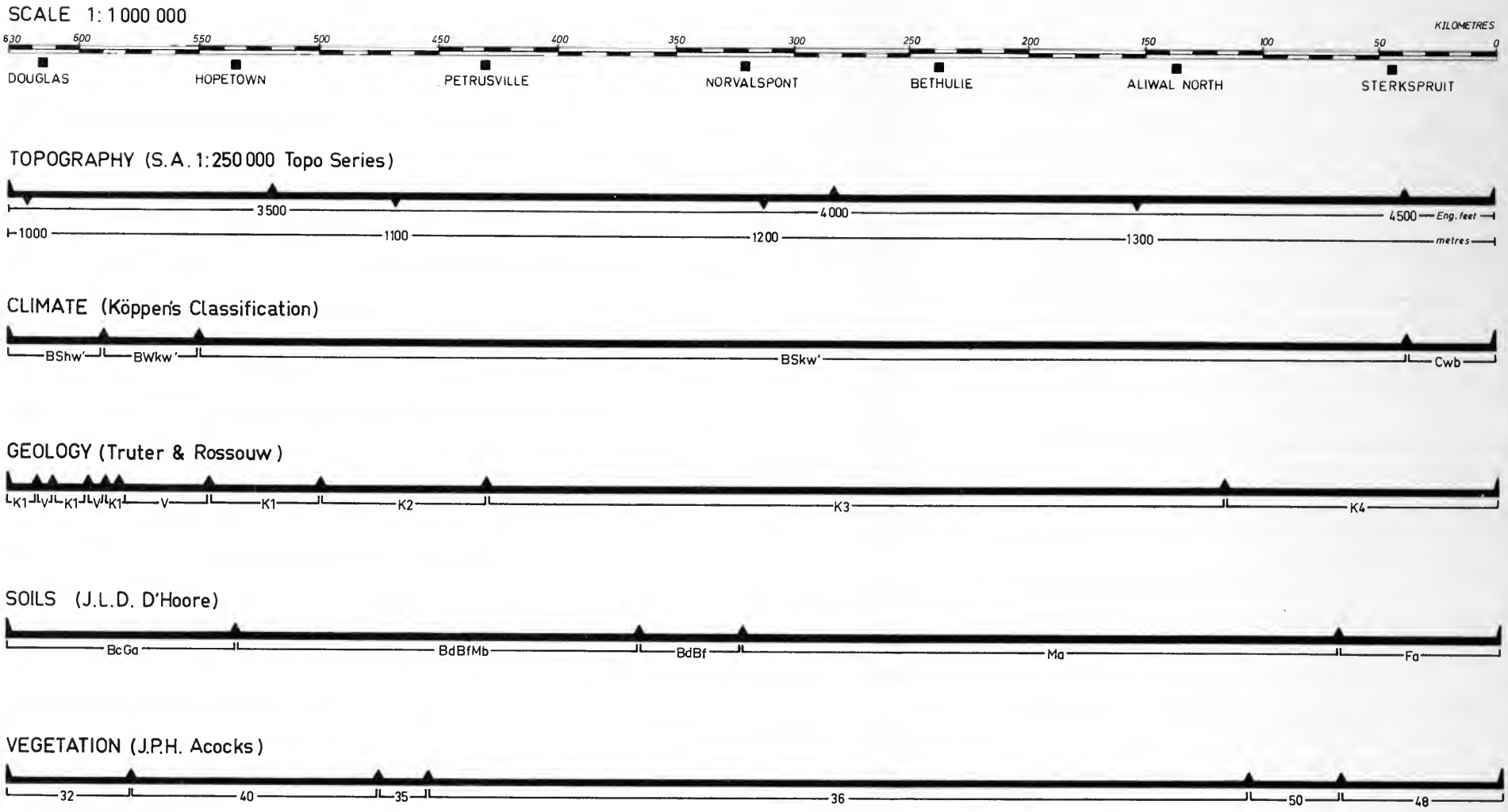
Due to overgrazing, the grassveld of this veld type can be replaced by Karoo and become Kalahari Thornveld invaded by Karoo. According to Acocks (1953) *Eriocephalus ericoides* in particular invades on the deeper sand, whereas on rocky hills and on calcrete the main invaders are several species of the Arid Karoo, the Central Upper Karoo and the Orange River Broken Veld.

More detailed surveys than the one by Acocks (1953) have not been carried out in the Upper Orange River area as a whole, and not many surveys dealing with only a small part of this area, or with a part of a veld type occurring in this area, have been carried out. Staples & Hudson (1938) mapped the Lesotho area adjoining the Orange River near the Herschel District as *Themeda triandra* Grassland and from this grassland-type derived *Eragrostis* Grassland. Bawden & Carroll (1968) indicate the same area as *Themeda-Cymbopogon-Eragrostis* Grassland, for which they list as the most important species *Themeda triandra, Cymbopogon plurinodis, Setaria flabellata, Elionurus argenteus, Heteropogon contortus, Tristachya hispida* and *Eragrostis* spp.

Mostert's (1967) discussion on the veld types of the Orange Free State Region, does not add additional botanical information to that already obtained from Acocks (1953).

An exception is the work of Hepburn (1919), who describes in rather more detail in a non-formal way communities of the Herschel District (called "Formations" by him), indicating the habitats of many species. He makes a main division into "formations of the veld", being the grassland communities of what Acocks calls the sandy *Cymbopogon-Themeda* Veld, the "formation of the slopes", being the slope communities in the same veld type, and the "formations of the altitudes above the Cave sandstone", being the communities

UPPER ORANGE RIVER (DIAGRAMATICALLY)



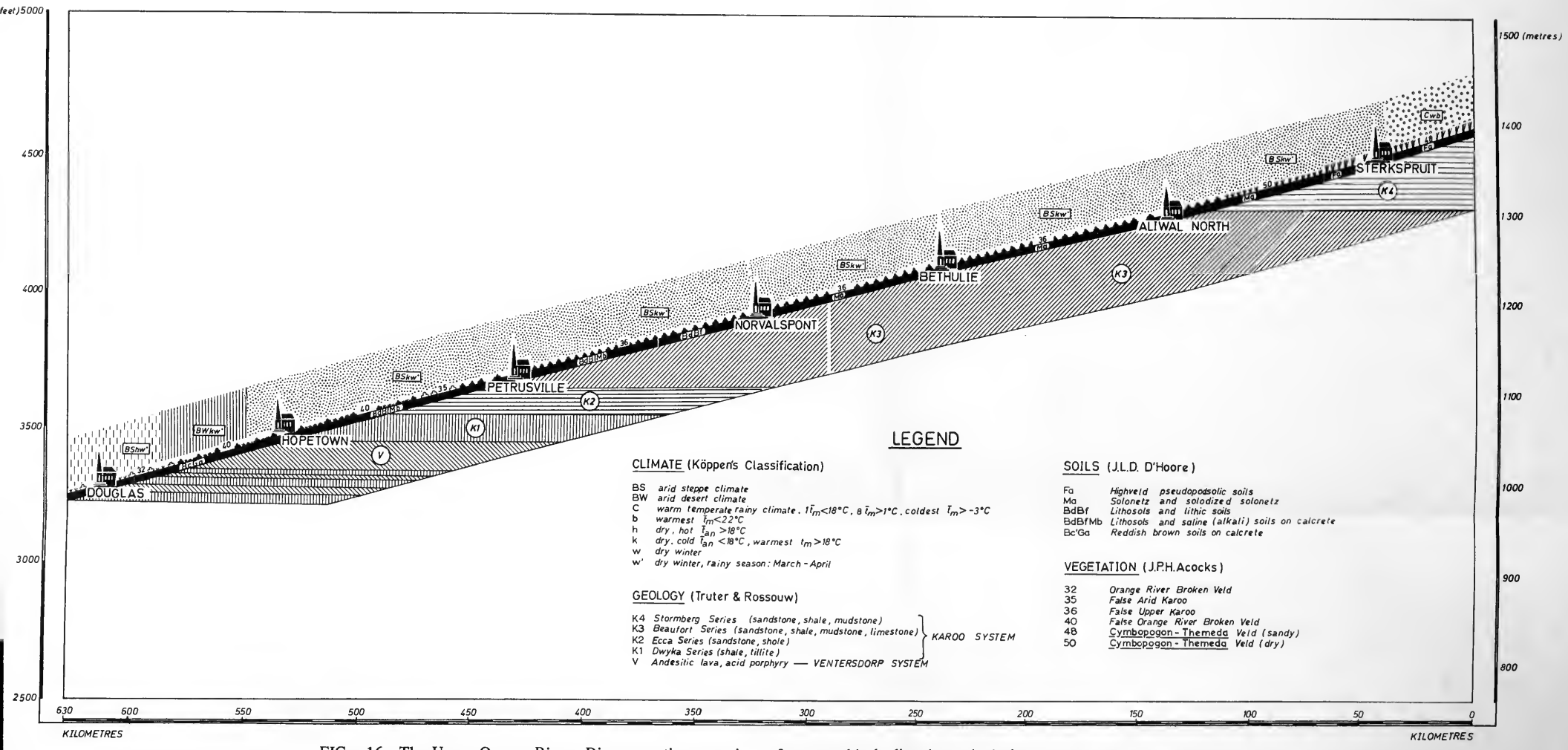


FIG. 16 - The Upper Orange River. Diagrammatic comparison of topographical, climatic, geological, soil and vegetation gradients

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of the *Themeda-Festuca* Alpine Veld according to Acocks.

Two ravine forest associations of the north-eastern Orange Free State, which are floristically not directly related, though they have a few species in common with communities occurring in the eastern part of the Upper Orange River area, have been described by Van Zinderen Bakker (1971).

Mostert (1957) carried out a detailed analysis of the vegetation near Bloemfontein and Brandfort largely falling into Acocks's (1953) central variation of the Dry *Cymbopogon-Themeda* Veld. On physiographic criteria he distinguishes three types of communities: (a) the communities of the valleys, which are comprised of the Valley *Acacia Bush* Community, the *Salsola* Community and the Valley Grass Community; (b) the communities of the slopes, which are comprised of the *Eberlanzia spinosa-Euphorbia mauritanica* Community, the *Euryops sulcatus-Euphorbia mauritanica* Community and other slope vegetation; (c) the grassland communities, which are comprised of the Valley Grassland Community, the *Themeda* Community and the Community on limestone. Floristic analyses are given of all these communities, according to the different methods used for communities on slopes as against the other communities.

On a karroid spot in the Dry *Cymbopogon-Themeda* Veld, near Bloemfontein, Potts & Tidmarsh (1937) mapped nine communities recognized in a non-formal way. The two *Euphorbia mauritanica* Communities later also distinguished by Mostert (1958) were identified in this survey. The various communities were analysed by means of belt and line transects.

Müller (1970) distinguishes ten communities, in the same veld-type near Bloemfontein and these include the two slope communities, described by Potts & Tidmarsh (1937) and Mostert (1958) and two scrub communities, also identified earlier by Potts & Tidmarsh (1937). Müller (1970) used Scandinavian School methods in his phytosociological study.

Association analysis was carried out by Roberts (1966) on data acquired on a relatively small, physiographically varied area east of Bloemfontein, comprising Thaba 'Nchu, in transitional *Cymbopogon-Themeda* Veld. In this detailed study Roberts distinguishes 28 communities, all of which are associated statistically with habitat factors such as slope angle, stoniness and moisture distribution.

On data, partly sampled in the central variation of the Dry *Cymbopogon-Themeda* Veld near Kroonstad, Scheepers (1969) carried out an association analysis and obtained a large number of groupings, most of which he can interpret ecologically.

A phytosociological survey according to the Zürich-Montpellier method was recently carried out by Werger (1973a) in False Upper Karoo vegetation of the Tussen die Riviere Game Farm in the southern Orange Free State. Several communities were distinguished and preliminarily described, and will be referred to in Chapter 5.

No detailed account on the Karoo or Kalahari Thornveld vegetation in the Upper Orange River area is available, although some studies on the Kalahari Thornveld in its more typical distribution area exist. As early as 1904 Passarge gave a general account of the vegetation of the Kalahari. Leistner (1967) studied the vegetation of the duneveld of the southern Kalahari in a non-formal way, whereas Leistner & Werger (1973) carried out a phytosociological analysis of the vegetation of the Kalahari Gemsbok National Park according to the method of Braun-Blanquet. They identified a number of associations that bear some resemblance to communities occurring in the Upper Orange River area.

Since it is generally accepted (De Klerk, 1947; Acocks, 1953, 1964; Phillips, 1956 to 1957; Mostert, 1967) that the area now covered by False Upper Karoo was still grassveld not so long ago, and that the area now covered with False Arid Karoo, Central Upper Karoo, False Orange River Broken Veld, Orange River Broken Veld and Kalahari Thornveld invaded by Karoo were previously also much grassier with far less extensive scrub cover of *Acacia mellifera* subsp. *detinens* and *Rhigozum trichotomum*, it is interesting to see what the early travellers reported from these areas.

In 1798 Sir John Barrow (1801) travelled northwards along the Seekoei River, just east of Colesberg, as far as its confluence with the Orange River. He then travelled for five days upstream along the Orange River and turned southwards again. On his map he marks at a position near the present Colesberg, "Fine meadows well clothed with grass", and slightly to the south of this locality "Excellent grazing country but much in fested (sic) with locusts". In his journal (1801) Barrow states:

"... we proceeded about twenty miles to the northward over a flat surface of country, consisting chiefly of meadow-ground, well watered by numerous springs and small rills, but destitute of every appearance of a bush or shrub. On every side were grazing a multitude of wild animals, as gnoos, and quachas, and hartebeests, and springboks, in such large troops as in no part of the country had before been observed. The place of our encampment was called Gordon's Fonteyn (south of Colesberg, near Andriesfontein), and near it stood the last Christian habitation, towards this quarter of the colony." (p. 253).

"... at the distance of a couple of miles on the south side (of the Orange River), were plains well covered with herbage." (p. 297).

"On the fifth day we left the river, and, turning off to the southward, travelled over a flat country of a strong clayey soil, well covered with fine grass, but destitute of wood or bushes, and ill supplied with water." (p. 301).

Andrew Smith travelled in 1834 to 1836 with his expedition from Graaff-Reinet via Colesberg, Philippolis and Bethulie to the present

north-eastern Orange Free State area and Lesotho. He turned back to Philippolis, travelled up to Griquatown, the Limpopo and the Transvaal and returned to Graaff-Reinet via Griquatown and the present Hopetown. In his diary he writes (Kirby, 1939) about the country near Gordon's Fontein:

"The country over which we travelled was almost destitute of vegetation: only thinly covered by dwarf black bushes of from six inches to a foot in height. Towards the centre of the flats patches of coarse grass and rushes occurred here and there." (Vol. 1, p. 62);

and near Colesberg:

"The face of the country exhibited a most barren appearance, nothing green to be seen; any grass that existed was dry and withered (because it was winter when Smith travelled there). The short bushes were all in the same condition, so that it is quite impossible for cattle or sheep to procure even a sufficiency to support existence ... (The white farmers) intend purchasing wool sheep with the compensating money (for release of the slaves), the prejudice against them having quite disappeared in the Graaff Reynet district. They remark that the country they inhabit is not calculated to support the large troops of African sheep which they possess, but they think it would sustain sufficient wool sheep to enable them to live comfortably." (Vol. 1, p. 63).

The border of the Cape Colony was in those days formed by the Orange River. On the vegetation north of the Orange River near Philippolis Smith remarks (Kirby, 1939):

"... the old grass stood rather more abundant" (Vol. 1, p. 79); and

"on flats, but especially on the hills, an abundance of dry grass" (Vol. 1, p. 81);

and near Bethulie:

"the road extended across five flats covered with a little dry grass. Almost no bush." (Vol. 1, p. 84); and

"The flats have scarcely a bush upon them, and the grass grows in tufts closely set together. There are two sorts of grass occurring, both sour and sweet grass. The latter is the most abundant. The grass on the hills is also said to be sour. Amongst the rocks on the sides and tops of the hills a few stunted trees and bushes." (Vol. 1, p. 89).

Smith makes many more remarks on the abundance of grass in these areas.

Collins, who lived for a while north of the Orange River, writes (Collins, 1965), that in 1849 the veld in the vicinity of Smithfield contains "thousands of broad acres of good and wholesome pasturage for all kinds of live stock, ..." (p. 11). Also Casalis (1933), without referring directly to the vegetation, reports on the huge herds of antelopes in the area at that time, indicating that the grazing value of the veld must have been good.

From these reports, it is clear, that at the end of the eighteenth century the veld near the present Colesberg, then outside the borders of the Cape Colony, had an abundancy of grass. Thirty-five years later, after the Upper Orange River had been the border for ten years, this vegetation had been destroyed and replaced by dwarf scrub. In the area north of the Orange River, not yet included in the colonized areas, grassland was still the dominant vegetation type.

Further downstream Hinrich Lichtenstein crossed the Gariep (Orange River) in the early nineteenth century at a place called Priskab (Prieska) on his travels from Cape Town to the vicinity of Griquatown. He reports (Lichtenstein, 1811 to 1812) from this area, that "ganze ausgedehnte Flächen waren mit langem Grase bewachsen, ..." (Vol. 2, p. 389). South of the Orange River in this area he also observed *Rhigozum trichotomum* occurring in larger patches, and *Acacia mellifera* subsp. *detinens* scrub.

In 1811 William Burchell travelled more or less the same route and also reports *Acacia mellifera* subsp. *detinens* as a dangerous shrub (Burchell, 1822 to 1824).

Later Grisebach (1872) repeated this story, and Marloth (1887) commented upon it, thereby reducing the reputation of danger of this shrub. Proceeding on his journey from Priskab (Prieska) to Klaarwater (Griquatown) and from there to the confluence of the Ky-Gariep (Vaal River) and the Nu-Gariep (Orange River), Burchell reports on a variety of plants he collected and tells of how the Bushmen had burnt the grass, because the fresh green new grass would attract game. Somewhat further to the south he reports large grass-covered plains with scattered trees which he describes (*Boscia albitrunca*). He also reports on plains with *Rhigozum trichotomum* and "delightful pastures" (Vol. 2, p. 35). In 1813 Burchell travelled back from Litakun (near the present Kuruman), along the Upper Orange River towards the present Hopetown and Colesberg, but his journal unfortunately makes no mention of this trip.

Andrew Smith, on his way back from the present Griquatown along the Orange River towards the present Hopetown and Graaff-Reinet, in 1836, says (Kirby, 1939) that he found near Hopetown "fine grass", particularly on the slopes (Vol. 2, p. 294-295).

It may be concluded that although the shrubs *Acacia mellifera* subsp. *detinens* and *Rhigozum trichotomum*, which at present cover such extensive areas, occurred in the region in those days they were not as preponderant and that plains covered with grasses were a regular feature of the landscape.

The disappearance of the grasses and the encroachment of bush and dwarf shrub has been ascribed to overstocking, particularly of sheep, followed by trampling and overgrazing (Shaw, 1875; Marloth, 1908; Staples & Hudson, 1938; De Klerk, 1947; Acocks, 1953, 1964; Bayer, 1955; Phillips, 1956 to 1957; Volk, 1966b; Mostert, 1967; Giess, 1968). These authors say, that because the sheep graze the palatable grass species selectively and heavily, these plants die. On the bare spots the unpalatable bushes can establish themselves, and once present, can grow vigorously because the sheep will not touch them until no grass or other

palatable species are left. Trampling has the same effect in that it damages the weaker, shallow rooted grasses more than the dwarf shrubs and shrubs. Acocks (1966a) has recommended the adoption by farmers of non-selective grazing system (N.S.G.), in which many smaller camps (paddocks) are each grazed intensively over short periods followed by longer periods of rest. In this way Acocks expects the original grassveld to regenerate.

Walter (1939, 1962) does not discuss this grazing factor for the False Upper Karoo area, but regards factors in soil type and moisture distribution of great importance in the present mosaic of shrub, dwarf shrub and grass. For the zonal savanna regions (Walter, 1954a), which also include the vicinities of Douglas, he discusses the bush encroachment in ecophysiological terms in a number of publications (Walter, 1939, 1954b, c, 1962; Walter & Volk, 1954). This savanna is, according to Walter, an equilibrium between grasses and woody plants, in which the grasses are in the majority. Because of grazing and trampling the relative quantity of the grasses is reduced and this means that the total quantity of water used by them will be less. Thus, at the end of the rainy season more water remains in the soil and this can be used by the woody plants. These woody plants increase vigorously, and with continued grazing this process is cumulative in favour of the woody plants.

Palynological studies of cores taken at Aliwal North dating back to between 12 600 ± 100 and 9 650 ± 100 BP, and at Florisbad near Bloemfontein, of which the oldest pollen preserved in the bottom layers is more than 48 000 years old, revealed that karroid and grassland vegetation alternated several times at these localities over this period of time. The alternations in vegetation were associated with changes in temperature. The cooler and more humid periods are represented by the grassveld and the warmer and drier conditions by the karroid vegetation. These cooler periods could be correlated preliminary to Riss and Würm glaciations and the Allerød Interstadial in Europe (Coetzee, 1967; Van Zinderen Bakker, 1969b).

2.7 LAND USE

Differences in climate, vegetation, topography and soils correspond with considerable differences in agricultural land use (compare Uhlig, 1965), but by far the main form of land use in the whole of the Republic of South Africa, and particularly so in the Upper Orange River area, is extensive farming (Tomlinson, 1970; Edwards, 1972; Edwards & Werger, 1972). For the Upper Orange River area this is clearly shown by the classifications in natural farming regions according to Pentz (1949), the Afdeling Ekonomie en Marke (1951) and the Kommissie van Ondersoek (1970), which are similar in their main divisions of the area. Pentz (1949) calls the area east of the vicinity of Aliwal North the intensive farming region of mixed character: stock farming and arable production are both main sources of income. West of the Aliwal North vicinity lies the semi-intensive and extensive farming region, in which sheep and cattle farming are the main sources of income. Also on the map of the Afdeling Ekonomie en Marke (1951) a main boundary traverses the Upper Orange River area in the vicinity of Aliwal North, east of which lies the mixed farming region and west of it the sheep farming region. The map of the Kommissie van Ondersoek (1970) shows that east of Aliwal North the Orange River virtually forms the boundary between the natural farming regions C_1 (Mixed Farming Region of the south-eastern Orange Free State) on the right-hand side of the river and D_2 (South Drakensberg Grazing Region) on the left-hand side of the river. The western boundary of these two areas is formed by the 500 mm isohyet

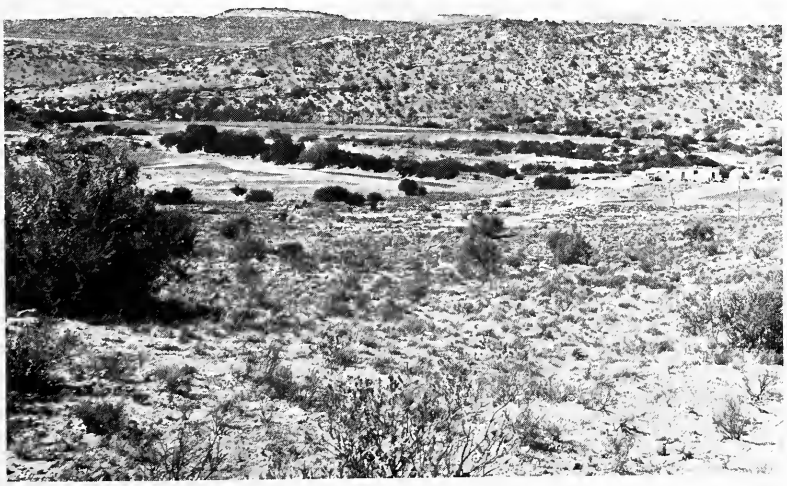


FIG. 17 - Scenery in the south-east Orange Free State, south of Rouxville. A small dam and some ploughed land in the vicinity of the farmhouse; in foreground overgrazed veld with *Eury-ops annae* and other dwarf shrubs. In background severely grazed Rhoo-Aloe-tum ferocis

and coincides broadly with Acocks's boundary between grassveld and False Upper Karoo. West of this boundary lies the Extensive Small Cattle Region, subdivided into an Eastern (F_1) and Central (F_2) part with a common boundary in the Upper Orange River area from De Aar via the vicinity of Hopetown towards Douglas. In the C_1 region farming consists mainly of crop production (maize, grain sorghum, groundnuts and rye) and stock farming. The considerable number of farms of a subeconomic size in this region form a serious problem. In the D_2 region, cattle and sheep farming on natural veld is the main practice. The carrying capacity of the grasslands in the C_1 and D_2 regions in the vicinity of the Orange River is about 1 to 2,5 hectares per beast or per 7 sheep (Rattray, 1960). In the F_1 and F_2 regions mainly extensive farming with Merino sheep is practised for wool and mutton production. The carrying capacity here is 1 to 2,5 hectares per sheep (Rattray, 1960). In the F_1 region, horse breeding is also important (Kommissie van Ondersoek, 1970).

In the grassveld area east of Aliwal North (C_1 and D_2 region) deterioration of the natural veld, in the sense of encroachment of Karoo bushes and erosion of the top soil, is serious (Figs 13, 14 and 17) (Immelman, 1967; Kommissie van Ondersoek, 1970). It is generally accepted that mismanagement of the veld through overstocking, trampling and incorrect grazing systems are the main reasons for this situation, as already mentioned above. Social and economic factors also play an important role in the continuity of this deterioration process (Immelman, 1967; Roberts, 1968). In a detailed scheme Roberts (1965) shows how this mismanagement of the veld leads to an ultimate decrease in productivity by a sequential process.

Veld-burning is regarded at least partially as an ancient and natural factor in the ecology of the South African veld (Bayer, 1955; Pienaar, 1956; Killick, 1963; Walter, 1968; Scott, 1970) and is reported to have a favourable effect on the eradication of Karoo bushes in the grassveld of Lesotho (Staples & Hudson, 1938). Others, however, (e.g. Pienaar, 1956) have warned against the use of fire in veld management. Alternatively, improved grazing systems have been recommended for reclamation of more valuable pastures in the areas invaded by Karoo bushes (Staples & Hudson, 1938; Tidmarsh, 1947; Acocks, 1966a). In the False Upper Karoo area some farmers have experimented with sowing *Eragrostis curvula* seed after ripping the surface soil. Particularly in the Herschel District the veld is in a very poor condition (Aircraft Operating Company, 1967). Since the quantity of cattle rather than their quality is still an important status determining factor in this African society, the problem of overstocking remains difficult to solve in this tribal area.

Cultivation of crop plants is practised only on a limited scale in the Upper Orange River area. In the Herschel District maize, other cereals, grain sorghum, vegetables and fruits are grown in small fields by the local African population. Small areas are also afforested with *Eucalyptus* which is utilized as fuel. *Opuntia* is planted too, to serve as additional cattle and sheep fodder.

Opuntia is also grown in the remaining part of the Upper Orange River area for the purpose of additional fodder, although the cultivation of lucerne under irrigation on the narrow zones of alluvial deposits along the river-bed is a more common practice. Usually the riverine forest, woodland and scrub is cleared for this purpose. Just upstream from Hopetown this riverine zone under cultivation is wider and some cotton is grown. Near the Orange-Vaal confluence a wider zone is under cultivation, particularly along the Vaal River.

An area comprising about 30 000 ha in all and consisting of three reserves, is devoted to nature conservation in the Upper Orange River area. The reserves are the Tussen die Riviere Game Farm at the Orange-Caledon confluence (about 23 000 ha), the Orange River Fisheries Station at Oviston (2 580 ha) and the Rolfontein Nature Reserve at the P.K. le Roux Dam (5 200 ha), all preserving False Upper Karoo vegetation (Edwards *et al.*, 1971; Edwards & Werger, 1972; Edwards, 1974). Besides nature conservation these areas are also used for recreation, as is the large Hendrik Verwoerd Dam.

Data on the area occupied by urban settlements roads and railways in the Upper Orange River area are not available, but these areas are not extensive.

An interesting feature near Philippolis, where the Orange River flows through a deep, steep-sided valley, is that the farms here all have a narrow path down the side of the valley to the river. In the old days this path was mainly used to collect *Osyris lanceolata*, which grows on the steep valley sides, and whose bark was used for the tanning of skins and leather. The local farmers took its bark to Philippolis in order to obtain ready cash to buy those goods which they could not provide for themselves.

2.8 CONCLUDING REMARKS ON THE PHYSIOGRAPHY OF THE AREA

The overriding physiographical feature according to this description of the Upper Orange River area is that of a gradient in the direction of the river course. From where the Orange River enters the Republic of South Africa down to where it is joined by the Vaal River, there is a steady decrease in altitude and in relief, an increase of desert conditions, an increase in xeromorphic structure in the vegetation types from grassveld to open karroid dwarf shrub, a stepwise change from the strata of the uppermost series of the Karoo System to those of the lowest, a change from pseudopodzolic soils via solonetzic to desert soils, from a mixed farming region with stock and arable farming to a region with stock farming on an extensive scale. It is, however, still possible to divide the area into three more or less clearly

defined subunits on the basis of eco-geographical characters (Fig. 16):

1. the high lying, dissected area east of Aliwal North, with a temperate tropical climate. Its geological substrate consists of Molteno, Red Bed and Cave Sandstone strata, the soils are largely pseudopodzolic, the vegetation consists mainly of grassland, and the land use is mainly of the mixed farming type;
2. the long middle area from Aliwal North to the P.K. le Roux Dam, with a drier and hotter steppe climate, less relief, on Beaufort strata, with solonetzic and desert soils, False Upper Karoo dwarf shrub and grass vegetation, and semi-extensive to extensive stock farming;
3. the lower lying, mainly flat area west of the P.K. le Roux Dam with a sub-desert climate, where the geological substrate is formed by the Ecca and Dwyka Series of the Karoo System and by the Ventersdorp lavas, with several pans. Soils are largely lithosols and sandy Kalahari soils on calcrete supporting mainly genuine Karoo vegetation types. Only extensive stock farming, primarily with sheep, is practised.

Phytogeography

The entire Upper Orange River Valley belongs to the African Subkingdom of Paleotropis. A detailed discussion of phytogeographical aspects concerning the area is given by Werger (1973b). From that account it becomes clear that a meaningful chorological subdivision of the Upper Orange River area results in the following pattern:

(a) east of Aliwal North on mesic sites: Afro-montane Region;
(b) between Aliwal North and the escarpment near Petrusville and east of Aliwal North on less mesic sites: Zambesian Domain of the Sudano-Zambesian Region;
(c) west of the escarpment near Petrusville: Karoo Domain of the Karoo-Namib Region.

Detailed data on the distribution of species within the borders of the Republic of South Africa are, unfortunately in an unpublished form, in the possession of Mr J.P.H. Acocks. In a recent paper on the distribution of grasses Acocks (1971) recognized nine patterns. On a somewhat coarser scale these patterns seem to confirm that in the Upper Orange River area a major division exists separating his pattern 1, from his patterns 3, 4 and 8. This would affirm the subdivision into the Karoo-Namib Region, including the southern Kalahari and the Sudano-Zambesian Region, to which the eastern grasslands and the False Upper Karoo belong.

Without attempting a more detailed chorological subdivision of the study area the following lists enumerate some species occurring in the study area, which in southern Africa, are typical of the phytogeographical pattern outlined above. Information for these lists is mainly derived from Acocks's unpublished distribution maps (Acocks, n.d.) with some additional information taken from Weimarck (1941), Hedberg (1965), Chapman & White (1970) and Bamps (1971).

Species typical of the Afro-montane Region are *Carex spicato-paniculata, Cliffortia linearifolia, Clutia pulchella, Merxmuellera disticha, Festuca caprina, F. longipes, Hypericum aethiopicum, Leucosidea sericea, Ochna atropurpurea, Rhus dentata, R. divaricata, Rubus ludwigii* and *Satureja biflora.*

Species occurring mainly in the Afro-montane Region of southern Africa and in the Cape Kingdom are *Blechnum australe, Festuca scabra, Gerbera piloselloides, Halleria lucida, Helichrysum odoratissimum, H. rosum, Helictotrichon longifolium, Heteromorpha arborescens, Kiggelaria africana, Koeleria cristata, Linum thunbergii, Melica decumbens, Metalasia muricata, Mohria caffrorum, Myrsine africana, Pentaschistis setifolia, Rhamnus prinoides, Kobresia sparteum, Silene undulata* and *Stachys aethiopica.*

Typical Capensis species occurring in the study area are probably only *Antizoma capensis, Asparagus capensis, Ehrharta erecta* and *Erica caffra.*

Species with a Sudano-Zambesian distribution pattern include *Achyranthes aspera, Anthospermum rigidum, Aristida bipartita, Blepharis integrifolia* (mainly south-western part), *Brachiaria serrata, Celtis africana, Commelina africana, Cussonia paniculata* (mainly on mountainous sites), *Cymbopogon excavatus, C. plurinodis* (also in Capensis), *Dicoma anomala, Elionurus argenteus, Eragrostis capensis* (also in Capensis), *E. chloromelas, E. gummiflua, E. plana, E. racemosa, Euclea crispa, Euphorbia clavarioides* (mainly southern part), *E. striata, Haplocarpha scaposa, Harpochloa falx, Helichrysum caespititium, H. nudifolium, H. rugulosum, Hermannia depressa, Heteropogon contortus* (also central parts of South Africa and in Capensis), *Hyparrhenia hirta* (also in Capensis), *Lactuca capensis, Microchloa caffra, Polygala amatymbica, Rhus erosa* (southern part only), *Rhynchosia adenodes, Schistostephium crataegifolium, Setaria flabellata* (also in Capensis), *Themeda triandra* (also in Capensis and Afro-montane Region), *Trichoneura grandiglumis* and *Walafrida densiflora.*

Species with a typical Karoo-Namib distribution pattern include *Acacia mellifera* subsp. *detinens, A. erioloba, Aizoon schellenbergii, Aloe claviflora* (mainly southern part), *A. hereroensis, Aptosimum albomarginatum, Peliostomum leucorrhizum, A. marlothii, A. spinescens, Asthenatherum glaucum, Barleria lichtensteiniana, B. rigida, Boscia albitrunca, Cenchrus ciliaris, Cleome angustifolia* subsp. *diandra, Enneapogon desvauxii, E. scaber, Eragrostis brizantha, E. nindensis, E. echinochloidea, E. porosa, Eriocephalus pubescens, E. spinescens, Euphorbia aequoris* (mainly southern part), *Fagonia sinaica* var. *minutistipula, Fingerhuthia africana,*

Hermannia abrotanoides, H. desertorum, H. spinosa, Hoodia gordonii, Limeum aethiopicum, Lycium prunus-spinosa, Microloma massonii, Monechma desertorum, M. divaricatum, M. incanum, Nestlera minuta (mainly southern part), *Pentzia incana, P. spinescens, Phaeoptilum spinosum, Plinthus cryptocarpus, P. karooicus, Psilocaulon absimile, Pteronia glauca* (mainly southern part), *P. sordida, Rhigozum trichotomum, Sarcocaulon patersonii, Senecio longiflorus, Stipagrostis ciliata, S. namaquensis, S. obtusa, Thesium hystrix* (mainly southern and eastern parts) and *Zygophyllum gilfillani.*

Species having their main distribution in the central parts of South Africa, restricted to a more or less narrow zone on both sides of the boundary between the Sudano-Zambesian and the Karoo-Namib Regions, include *Aloe broomii* (mainly southern part), *Aptosimum depressum, Aristida diffusa* var. *burkei, Asparagus striatus* (mainly southern part), *Felicia muricata, Blepharis villosa* (mainly southern part), *Chrysocoma tenuifolia, Convolvulus boedeckerianus, Cyperus usitatus, Dimorphotheca cuneata* (mainly southern part), *Enneapogon scoparius, Eragrostis lehmanniana* (also Karoo-Namib Region), *E. obtusa, Eustachys mutica* (also Sudano-Zambesian Region), *Geigeria filifolia* (also Karoo-Namib Region), *Gnidia polycephala, Haworthia tesselata, Helichrysum dregeanum* (towards Sudano-Zambesian Region), *H. lucilioides* (towards Karoo-Namib Region), *H. zeyheri, Hermannia coccocarpa, H. linearifolia, H. pulverata, Hibiscus marlothianus, Indigofera alternans* (also Karoo-Namib Region) *Lessertia pauciflora, Mariscus capensis, Mestoklema tuberosum, Nananthus vittatus, Nenax microphylla* (towards Sudano-Zambesian Region), *Nestlera conferta, Osteospermum leptolobum, O. scariosum, Pachypodium succulentum* (mainly southern part), *Pegolettia retrofracta* (also Karoo-Namib Region), *Pentzia globosa, P. sphaerocephala, Phymaspermum parvifolium, Pterothrix spinescens, Rhigozum obovatum, Rhus ciliata* (mainly northern part), *R. undulata* var. *tricrenata* (rather widespread), *Sutera halimifolia, Tragus koelerioides, Trichodiadema pomeridianum* and *Walafrida saxatilis* (towards Sudano-Zambesian Region).

Species with a wide distribution not exemplifying the chorological classification given above, include *Acacia karroo, Aristida congesta, A. adscensionis, Asclepias fruticosa, Asparagus suaveolens, Boophane disticha, Eragrostis curvula* (not in Karoo-Namib Region), *Olea africana, Pentarrhinum insipidum, Pollichia campestris, Rhus pyroides, Rhynchelytrum repens, Sarcostemma viminale, Talinum caffrum* (not in Capensis), *Tragus berteronianus* and *Ziziphus mucronata* (not in Capensis).

Definition of study area and methods

The study area comprises the valley of the Upper Orange River from where it crosses the border between Lesotho and the Republic of South Africa near Palmietfontein, down to its confluence with the Vaal River at Mazelsfontein. As mentioned in Chapter 2.1, this amounts to a length of 656 km, measured along the river-bed. The valley was theoretically delineated as follows: Where the river cuts deeply through a plateau the valley could easily be determined by the edges of the plateau. In strongly dissected areas, the valley limits were defined along the highest ridges in the vicinity of the river in such a way that the study area included the areas which drained directly, or virtually so, into the Orange River. In the flat area downstream from Petrusville, the outer edges of the valley were taken as the highest points in the slightly convex landscape.

In practice, however, the study area was usually taken as being wider than the theoretically delineated valley. Relevés were made on the plateau outside the edges of the valley, and up to about 10 km away from the actual river course in flat areas. Hence the survey included the vegetation which was no longer influenced directly by the river or by the land-forms determined by the river. This meant that in practice the study area measured more than 3 000 km².

This area was surveyed according to the methods of the Zürich-Montpellier School. The value of these methods in a vegetation survey were discussed by Werger (1973b, 1974a) and their applicability to tropical vegetation studies by Werger (1977). The concepts and techniques constituting the Zürich-Montpellier methods were discussed in detail by Werger (1973b, 1974b). Since Werger's (1973b) discussion, Westhoff & Van der Maarel (1973) also published a review of methods and concepts of the Zürich-Montpellier School.

In the study area 561 relevés were layed out and sampled, which means a sampling intensity of approximately one relevé per five km² (Fig. 18). The sizes of the relevés varied between 25 and 100 m² according to structure and floristic richness

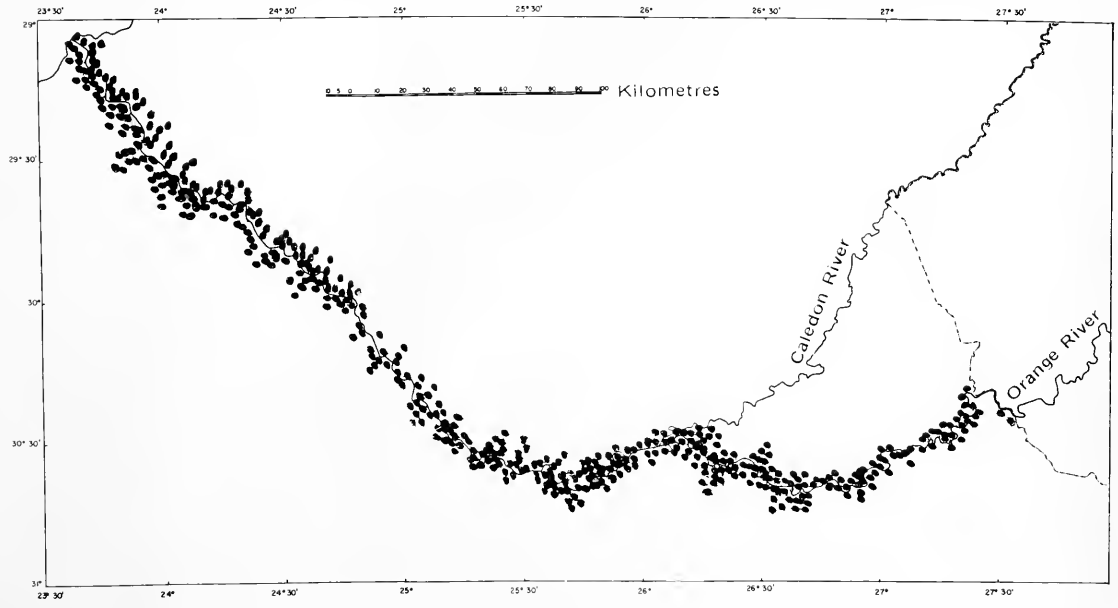


FIG. 18 - Distribution of relevés in Upper Orange River area

of the vegetation, which is discussed by Werger (1972, 1973b).

With a few species taxonomic difficulties were experienced. Partly owing to the extreme richness of the South African flora, several taxonomic groups have not been revised for more than half a century. As a result, the species concept in certain groups is not always unequivocal, which makes pertinent identification impossible. The following taxonomic vaguenesses should be considered in this light:

1. No distinction was made between *Cotyledon decussata* Sims and *Cotyledon orbiculata* L., since no consistent difference between the two species could be found. Occurrences of any of these two species were listed and entered in the table under the label *Cotyledon decussata-orbiculata* complex.
2. Similarly, the species *Eriocephalus pubescens* DC. and *Eriocephalus ericoides* (L.f.) Druce have not been distinguished from one another. If these are clearly different species, it is likely that in the communities on Kalahari sand (viz. Chapter 5.6) *Eriocephalus ericoides*, not *Eriocephalus pubescens*, occurred constantly.
3. Extremely difficult taxonomically is the *Eragrostis curvula* Nees - *Eragrostis chloromelas* Steud. complex. In the present study a narrow concept of *Eragrostis chloromelas* Steud. and a broad concept of *Eragrostis curvula* Nees is maintained.
4. Individuals identified with the name *Nestlera minuta* (L.f.) DC. could clearly be separated into two forms, a grayish one, mostly occurring on calcrete, and a more bronze green coloured one. The gray form was recorded as *Nestlera minuta* forma, and the bronze green form as *Nestlera minuta*.
5. *Lycium salinicolum** is taxonomically not clearly delineated. In the present study a rather broad concept of the species is maintained.
6. The species *Tarchonanthus camphoratus* comprises a range from narrow-leafed to broad-leafed forms, which are in their extremes clearly distinct, but various intermediate forms exist. A broad concept of *Tarchonanthus camphoratus* has been maintained in the present study, including all these forms.

In Tables 11 and 6.6 the name *Stachys burchelliana* is wrong and should read *Stachys rugosa* var. *linearis*.

In preparing the tables the apparatus described by Müller *et al.* (1972) was used and found very efficient.

It was decided not to reject transitional or unrepresentative relevés on prejudice. When specific relevés with reference to the total table appeared to be clearly heterogeneous, or their total number of species was so low that it evidently showed their fragmentary nature, these relevés were rejected for inclusion in the table after having been interpreted. However, relevés were not omitted when they represented transitional stages between recognized table units. Thus, in two cases relevés taken on the outer edge of the riverine woodland, so clearly contained a mixture of riverine and surrounding Karoo vegetation that they were rejected. Twenty further relevés were of such a fragmentary nature in floristic composition, obviously owing to extreme overgrazing and trampling, that although they were ecologically interpreted, they are not represented in the tables.

The present survey does not cover the entire range of specific syntaxa and taxa, and being the

*The *Lycium* species are at present under revision

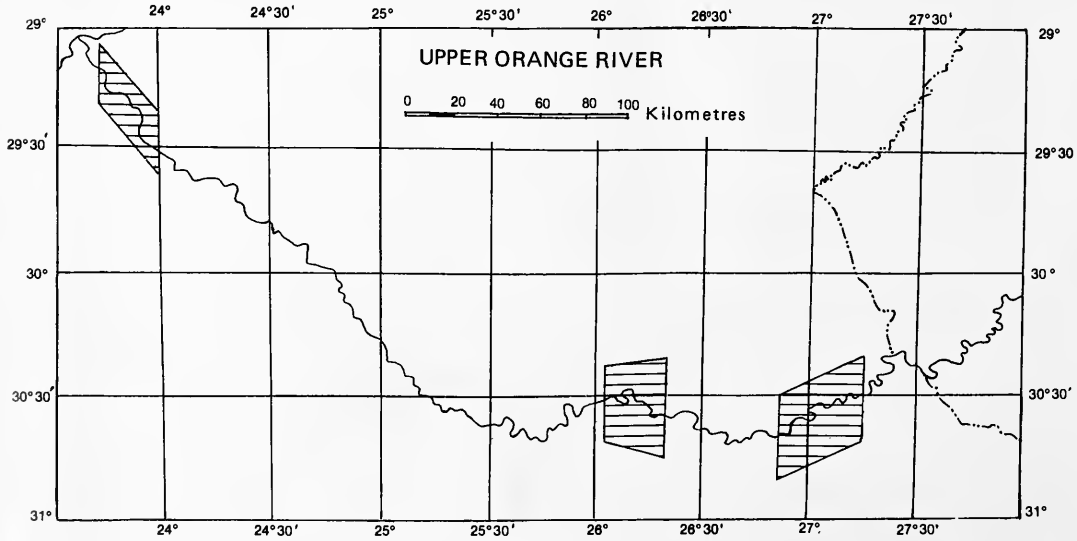


FIG. 19 - Situation of vegetation maps

VEGETATION MAP
of the
UPPER ORANGE RIVER AREA

SECTION: ALIWAL NORTH 3026DB
and LADY GREY 3027AC + CA

MAPPING: M. J. A. WERGER, 1973

DRAWN BY DEPT. OF ILLUSTRATION
FAC. SCIENCES, NIJMEGEN

27° 00'

30° 30'

26° 52'

27° 15'

30° 45'

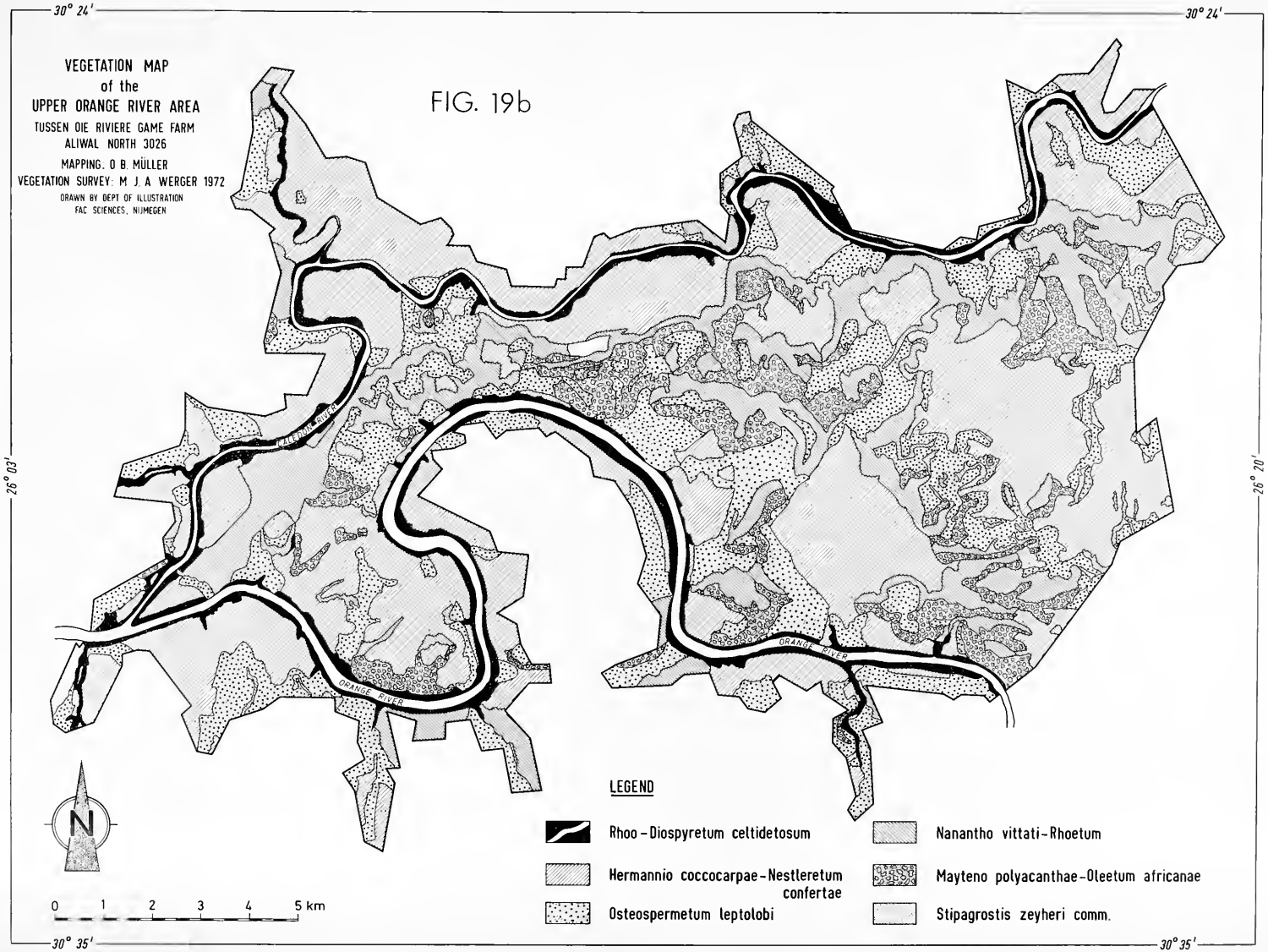
ORANGE RIVER

FIG. 19a

LEGEND

- ploughed land
- Rhoo-Diospyretum celtidetosum
- grassland
  - 1 Brachiaria serrata-Elyonurus argenteus comm.
  - 2 Eragrostis plana-Eragrostis gummiflua comm.
  - 3 Pentzia globosa-Eragrostis curvula comm.
- Indigofero spinescentis-Rhoion erosae

0 1 2 3 4 5 6 7 8 9 10 km


30° 24'
30° 24'
VEGETATION MAP
of the
UPPER ORANGE RIVER AREA
TUSSEN DIE RIVIERE GAME FARM
ALIWAL NORTH 3026
MAPPING. O B. MÜLLER
VEGETATION SURVEY: M J A WERGER 1972
DRAWN BY DEPT OF ILLUSTRATION
FAC SCIENCES, NIJMEGEN
FIG. 19b
26° 03'
26° 20'
ORANGE RIVER
ORANGE RIVER
N
0 1 2 3 4 5 km
LEGEND
Rhoo-Diospyretum celtidetosum
Hermannio coccocarpae-Nestleretum confertae
Osteospermetum leptolobi
Nanantho vittati-Rhoetum
Mayteno polyacanthae-Oleetum africanae
Stipagrostis zeyheri comm.
30° 35'
30° 35'

first comprehensive study according to the Zürich-Montpellier approach in South Africa, virtually no additional data are available from other sources. Therefore, it could not be established whether specific character species are local, regional or absolute character species and so only local character species and differential species have been distinguished. If species faithful to noda in the tables showed optima in more than one nodum, they were called differential species; otherwise they were called (local) character species. Species which were concentrated in more than one nodum, but had clearly their optimum in one specific nodum, were called (local) character species for the nodum in which they reached their optimum, and differential species for all other noda in which they were concentrated, as against the other noda from which they were absent or virtually so. In the tables, as well as in the descriptions of the syntaxa in Chapter 5, differential species are indicated by (d). The determination of species as character species in the present study remains to a certain extent a presumption. This uncertainty is minimal, however, because most associations have been sampled over the entire mesic-xeric gradient existing in the east-west direction in the study area and constituting the most important gradient there (compare Chapters 2 and 5). The associations occurring at either end of the study area, particularly the Rhamno-Rhoetum and the Melhanio rehmannii-Hermannietum spinosae, have not been sampled over the entire gradient mentioned. Therefore, some species typifying these associations and occurring only in these associations within the study area, appear to be character species but in reality are only differential species because they also occur frequently just outside the study area in other communities which have not been sampled. Based on such observations some species, mainly those typifying the Rhamno-Rhoetum and the Melhanio rehmannii-Hermannietum spinosae, have been distinguished as differential species and are indicated in the tables by (d).

All communities characterized clearly by a group of species labelled "character and differential species", and identified with specific environmental conditions which differ from other communities, were regarded as associations in the proper sense. One association is recognized, which is typified by a large group of differential species only. Some minor communities were not given any syntaxonomical rank, since the data available for these communities were considered insufficient. Also the eastern grassland communities were not given rank for reasons mentioned in Chapter 5.2.

In two cases an alliance was provisionally proposed. Some of the communities recognized are not structurally homogeneous: shrubby facies alterate with facies with only few shrubs, although the floristic composition of the two facies stays the same apart from this shrubby species. For a detailed discussion of this problem see Werger (1973b) where further references are given.

Owing to lack of time, the vegetation in the Upper Orange River area has not been mapped entirely. However, in three different parts of the area the vegetation was mapped to a scale of 1:100 000 (Figs 19, 19a, 19b and 19c). These areas are situated near Lady Grey, near Bethulie and near Hopetown. This even distribution of the mapping areas over the three subunits of the Upper Orange River area (compare Chapter 2.8) ensured that most of the vegetation types described in Chapter 5 appear on the maps.

The area near Lady Grey comprises part of the topographical maps 3027 CA, 3027 AC and 3026 DB. The area near Bethulie comprises the Tussen die Riviere Game Farm covering parts of topographical maps 3026 AC, 3026 AD, 3026 CA and 3026 CB. The area near Hopetown covers parts of topographical maps 2923 BB, 2923 BD and 2923 DB.

The areas near Lady Grey and near Hopetown have been mapped from aerial photographs to a scale of 1:36 000. These aerial photo maps were subsequently corrected after field inspection. An area of at least 5 km on both sides of the river-bed has been included in the mapping. The vegetation types described in this report, however, occur over wider areas much further away from the river-bed.

Vegetation types covering areas of less than 70 x 180 m have not been mapped, because they could not be shown properly on the scale used (cf. Küchler, 1967).

The area near Bethulie was mapped by Mr D.B. Müller from aerial photos taken at a scale of 1:36 000.

Each vegetation type is identified by its own kind of hatching on the maps. In the main it was ascertained to which subtype the mapped vegetation at a certain locality belonged. This is indicated by the figures 1, 2 or 3 in the hatchings. If the subtype is not known no figure is inserted. In the map of the area near Lady Grey the boundaries between the various grassland types have not been given on the maps because they could not be determined on the aerial photographs. At each locality where the subtype was ascertained during field observation, it is indicated by a figure in the hatchings.

VEGETATION MAP
of the
UPPER ORANGE RIVER AREA

SECTION: DOUGLAS 2933BB

MAPPING: M. J. A. WERGER, 1973

DRAWN BY DEPT. OF ILLUSTRATION
FAC. SCIENCES, NIJMEGEN

ORANGE RIVER

29° 15'

23° 45'

24° 00'

29° 30'

FIG. 19c

LEGEND

Old land	ploughed land diamond diggings
Zizipho-Acacietum karroo	
Zizipho-Rhigozetum obovati	
Melhanio rehmannii-Hermannietum spinosae	
Monechmatetum incani	
Nestlero humilis-Pteronietum sordidae	stipagrostietum ciliatae typicum
Pentzio calcareae-Stipagrostietum	typicum acacietosum giraffae

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The plant communities *

5.1 THE RIVERINE COMMUNITIES (DIOSPYRION LYCIOIDIS)

(Table 4)

True vascular water-plant communities are virtually absent from the Orange River and its tributaries, probably due to the high silt load of the water, although the large, sudden floods of these rivers might also be an important factor in this respect (Butcher, 1933; Edwards, 1969). An inventory of water-plants occuring in the catchment area of the Orange River upstream from the Hendrik Verwoerd Dam drawn up by Nel (1972) revealed that thick and extensive floating mats of *Azolla filiculoides* Lam., a species known to be able to reproduce vegetatively at a vast rate (Sculthorpe, 1967; Moore, 1969), occur periodically in the Broekspruit, Bossiespruit, Brakspruit and a few other minor tributaries of the Orange River in the vicinity of Bethulie. At present, floating islands of this species, measuring up to 5 m in diameter, occur irregularly spread over the Hendrik Verwoerd Dam. A few other vascular water-plant communities in the Upper Orange River area are found in the small water reservoirs on farms. The most common of these is a community consisting of nearly pure stands of *Potamogeton pusillus* L. (Nel, 1972; Edwards & Nel, 1972).

Where dolerite dykes cross the river, rocky outcrops which are just above the waterline when the river is at low level, occur in the stream-bed. On these outcrops one regularly encounters extremely open stands of the loganiaceous shrub *Gomphostigma virgatum* (L.f.) Baill.

During the low-water season numerous small to extensive sand-banks occur in the river-bed (Fig. 22). Here temporary communities, in which neophytes can be important, often become established. Among the most common species (neophytes are indicated with (n); cf. Henderson & Anderson, 1966) are: *Agrostis lachnantha, Polygonum lapathifolium* subsp. *maculatum, Conyza podocephala, Conyza floribunda* (n), *Salsola kali* (n), *Xanthium strumarium* (n), *X. spinosum* (n), *Tagetes minuta* (n), *Bidens bipinnata* (n), *Aristida adscensionis, Chloris virgata, Argemone subfusiformis* (n), *Verbena officinalis* (n). On slightly more stabilized soil, and where the levees drop away into the river channel, these species also occur, together with *Senecio burchellii, Cynodon hirsutus, Mentha longifolia, Panicum laevifolium, Oenothera grandiflora* (n), *O. rosea* (n), *O. indecora* (n), *Chenopodium ambrosioides* (n), *Aristida junciformis, Eragrostis curvula, Cyperus esculentus, Artemisia afra,* and others. Trees and shrubs of *Salix capensis, S. babylonica* (n) and *Nicotiana glauca* (n) and open to dense stands of *Phragmites australis* are also often encountered here. The special adaption of these plants to their habitat, which is subject to flooding, silting and alternating dry and wet conditions is discussed by Ambasht (1968) in a paper on a floristically similar community on the banks of the Ganges.

Well developed levees occur along almost the entire Upper Orange River. Only were the river cuts a steep valley through a dolerite dyke or other hard rock, such as between Hopetown and Douglas where it cuts through the Ventersdorp lava, and through the hard Molteno sandstone in some places in the Herschel District, are these accumulations of fine sand alongside the stream channel absent (Fig. 9). On the levees, which can be up to 250 m wide, forest and scrub which is often referred to as "Mimosa-forest" by the early travellers, is found.

In the entire area from the Lesotho border to a few miles downstream from Colesberg the characteristic association on the levees is the Rhoo-Diospyretum (Table 4). Particularly characteristic for this association is the shrubby tree *Rhus pyroides* which is a constant character species and usually scores high cover-abundance values. Other character species of the Rhoo-Diospyretum are the grass *Bromus willdenowii,* the climbing herb *Rubia cordifolia,* the herb *Cineraria lobata* and the shrub *Melianthus comosus.* Differential species of this association against the Zizipho-Acacietum karroo are the spiny shrub *Asparagus suaveolens* and the grass *Melica decumbens.* Two subassociations of the Rhoo-Diospyretum occur in the Upper Orange River area. In the section between the Lesotho border and the vicinity of Norvalspont the subassociation celtidetosum is found, typified by the tree *Celtis africana* and in the lower layers *Achyranthes aspera, Pentarrhinum insipidum, Conyza podocephala* and *Artemisia afra* (Table 4) (Fig. 20). Between Norvalspont and the western limit of the Rhoo-Diospyretum, downstream from Colesberg, the subassociation acacietosum karroo occurs. Differential species of this subassociation is the tree *Acacia karroo* (Table 4) (Fig. 21).

In the westernmost range of the celtidetosum, between Goedemoed and Norvalspont, the *Acacia*

*For Braun-Blanquet Tables 4, 8-13, see inside back cover

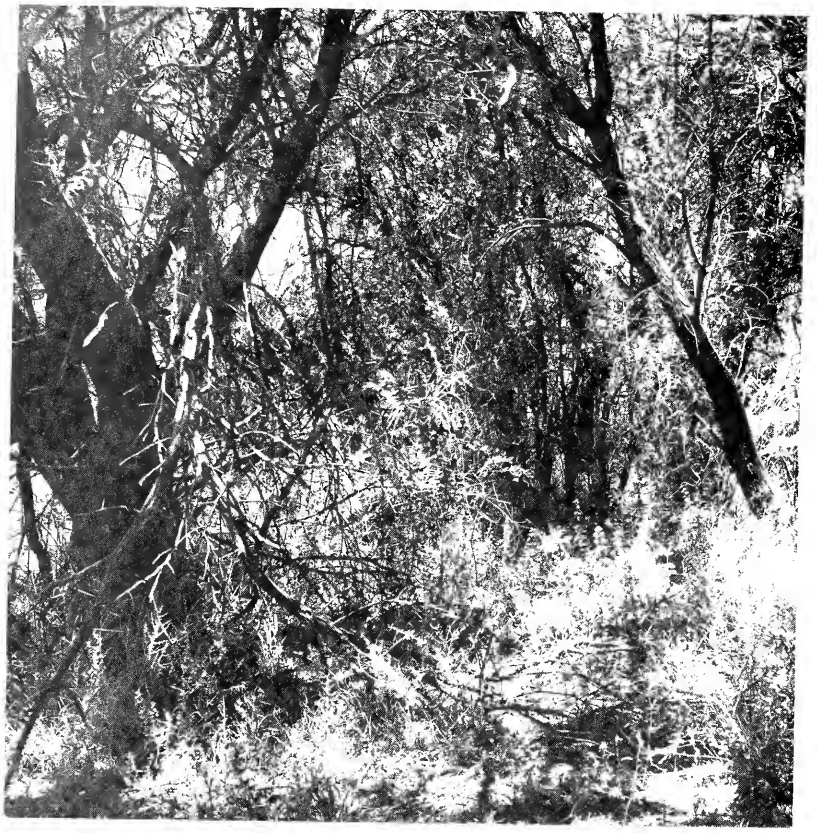


FIG. 20 - Rhoo-Diospyretum celtidetosum, variant with *Acacia karroo*, near Venterstad. This site has since been drowned by the waters of the Verwoerd Dam

FIG. 21 - Rhoo-Diospyretum acacietosum karroo near Norvalspont. Only relatively far away from the river is the vegetation as open as on this photograph. Note the abundance of *Acacia karroo* saplings

karroo - variant occurs, in which the differential species of the celtidetosum as well as *Acacia karroo* are present. A preliminary description of this variant was given by Werger (1973a) under the name *Acacia karroo-Celtis africana* Community.

In the remainder of the Upper Orange River valley, and even further downstream, the levees are covered by the Zizipho-Acacietum karroo (Figs 22 and 23). Character species of this association are the trees *Ziziphus mucronata* and *Rhus viminalis,* the shrub *Lycium austrinum,* the herb *Senecio burchellii* and the grass *Setaria verticillata,* whereas the grasses *Schismus barbatus* (d) and *Brachiaria marlothii* (d) and the hemiparasite *Viscum*

FIG. 22 - Orange River South of Douglas with several large sand banks. On both levées Zizipho-Acacietum karroo with in foreground *Ziziphus mucronata* and *Nicotiana glauca*

FIG. 23 - Zizipho-Acacietum karroo near Torquay, with *Acacia karroo, Nicotiana glauca* and *Setaria verticillata*

rotundifolium are differential species of the association against the Rhoo-Diospyretum (Table 4). *Acacia karroo,* which also occurs in similar quantities in part of the Rhoo-Diospyretum, can only be regarded as a constant and prominent companion species in the Zizipho-Acacietum karroo. A community that is floristically rather similar to the Zizipho-Acacietum karroo is mentioned by Mostert (1958) under the name "Valley *Acacia* Bush Community". Leistner (1967) and Leser (1971, 1972) reported a river-fringing woodland or thicket with *Acacia karroo* and *Ziziphus mucronata* from the upper parts of the Auob in South West Africa, and Leistner (1967) also reported such a community from the upper reaches of the Nossob, Molopo and Kuruman in the southern Kalahari.

The Rhoo-Diospyretum and the Zizipho-Acacietum karroo have a number of constant species in common and are combined into one alliance the Diospyrion lycioidis. The following species are character species of the Diospyrion lycioidis: the shrubs *Diospyros lycioides* subsp. *lycioides, Lycium hirsutum* and *L. arenicolum,* the climbers *Asparagus setaceus* and *Clematis brachiata* and the neophytic herbs *Atriplex semibaccata* and *Chenopodium murale. Diospyros lycioides* subsp. *lycioides* usually reaches high cover-abundance values (Table 4).

Infrequently, apart from the species mentioned above, the two associations contain a few accompanying species of which *Nicotiana glauca, Hebenstreitia integrifolia* and *Salsola glabrescens* are the most regular but still not frequent. Intruding species of the surrounding vegetation, particularly of the Karoo dwarf shrub vegetation, are found more often in the two associations of the Diospyrion lycioidis. The commonest of these Pentzio-Chrysocomion species (cf. Chapter 5.3) are *Felicia muricata, Chrysocoma tenuifolia, Eragrostis lehmanniana, Walafrida saxatilis* and *Pentzia globosa.* Thus, all constant species in the riverine forest and woodland are character or differential species for the various syntaxa and there are no constant accompanying species. In the more humid, temperate areas of the world this phenomenon is usually typical for syntaxa bound to extreme habitats - which represent exceptional cases. From a general ecological viewpoint, the levees on which the Diospyrion lycioidis communities occur, cannot be considered extreme habitats. However, they represent an exceptional situation in the generally extreme ecological conditions of all surrounding ecosystems. It is possibly the exceptional situation of the riverine communities, which brings about the lack of constant accompanying species.

The vegetation of the Rhoo-Diospyretum and the Zizipho-Acacietum karroo is usually three layered. Often the tree layer of 6 to 10 m high reaches cover values of between 60 and 90 %, but this figure can also be considerably lower mainly due to cutting by man. The shrub layer, varying in height from about 1 to 4 m, usually covers less than 40 %, but the shrub layer can cover considerably more than 40 %, particularly when the tree layer is open. The cover of the ground layer which is up to 0,70 m high, varies greatly, depending on biotic factors such as grazing and trampling. Total cover in both associations of the Diospyrion lycioidis is usually between 90 and 100 %.

Towards the edges of this fringing forest, where there is more light penetration into the lower strata, *Lycium hirsutum* and *L. arenicolum* tend to occur more abundantly than under the tall trees of *Celtis africana, Acacia karroo* or *Ziziphus mucronata.* Sometimes dense thickets of these spinous solanaceous shrubs occur. Thickets of *Lycium arenicolum* in particular can also be observed in open spots where farmers have cut away the

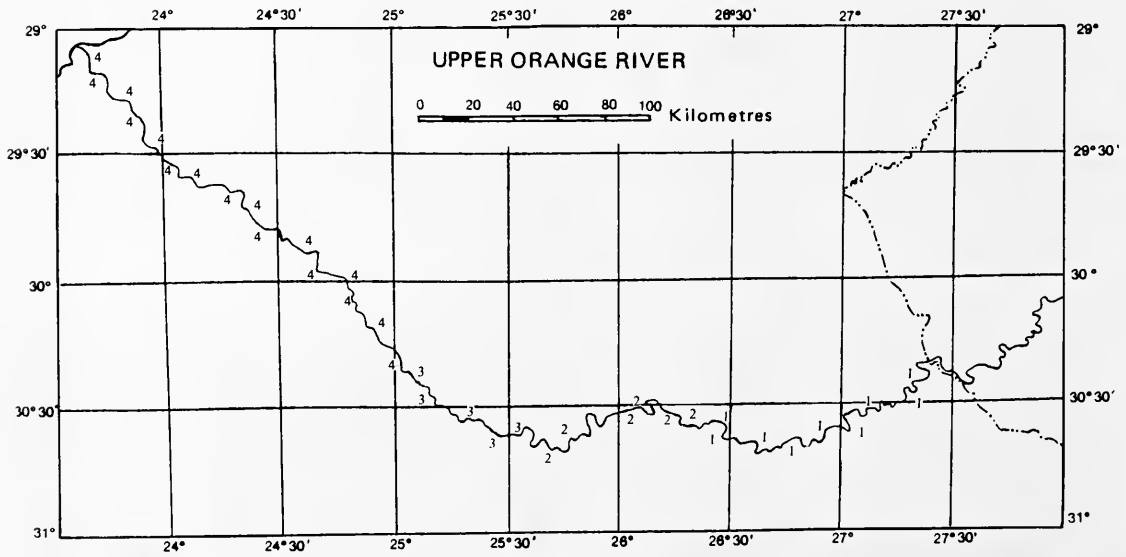


FIG. 24 - Distribution of Diospyrion lycioidis in Upper Orange River area. 1. Rhoo-Diospyretum celtidetosum; 2. *Acacia karroo* variant of Rhoo-Diospyretum celtidetosum; 3. Rhoo-Diospyretum acacietosum karroo; 4. Zizipho-Acacietosum karroo

large trees, as in the case of relevés 42 and 114.

The distribution pattern of the syntaxa of the Diospyrion lycioidis in the Upper Orange River valley shows a clear geographic gradient from east to west: from the Lesotho border to the vicinity of Goedemoed the typical form of the Rhoo-Diospyretum celtidetosum occurs; from the vicinity of Goedemoed to the vicinity of Norvalspont the *Acacia karroo*-variant of this syntaxon is found; from there to a few miles downstream from Colesberg the Rhoo-Diospyretum acacietosum karroo is found, and from there onwards the Zizipho-Acacietum karroo covers the levees (Fig. 24). The soil of the levees of the Upper Orange River over this whole range is of the same fine sandy type, over 3 m deep and with a neutral pH. The distribution of the various geological strata also does not correlate with the distribution of the syntaxa. Therefore, the likelihood of a distribution pattern due to a gradient in climate is an obvious conclusion. As described in Chapter 2.2 an east to west gradient of decreasing mean annual relative humidity at 14h00 and of precipation exists in the area, as well as a gradient of increasing temperature, evaporation and mean saturation deficit at 14h00. This gradient is reflected in the leaf structure of the vegetation layer that is most exposed to these macroclimatic factors, viz. the tree layer. In the eastern part of the area the prevailing tree is *Celtis africana* with leaves of a mesic type, followed westward by *Acacia karroo* with microphyllous leaves of a less mesic type and finally *Ziziphus mucronata* with coriaceous leaves, becomes an important tree. In the lower layers there is not such a difference in leaf types between the various syntaxa, because the riverine forest everywhere is fringed on the sides by relatively dense scrub, which maintains mesic conditions inside the forest (Potzger, 1939). The climatological classifications according to Walter & Lieth (1960) and UNESCO-FAO (1963) correlate well with the distribution pattern of the syntaxa of the Diospyrion lycioidis (cf. Chapter 2.2.8). Walter & Lieth's zone 113a covers the area of the typical form of the Rhoo-Diospyretum celtidetosum, and their boundary between zones 114a and II(III)a coincides with that between the Rhoo-Diospyretum and the Zizipho-Acacietum karroo. UNESCO-FAO's intermediate temperate tropical zone covers the entire Rhoo-Diospyretum celtidetosum, the accentuated temperate tropical zone the Rhoo-Diospyretum acacietosum, and the attenuated sub-desert zone the Zizipho-Acacietum karroo. The borderline between the typical form of the Rhoo-Diospyretum celtidetosum and the *Acacia karroo*-variant of this subassociation seems to coincide with the 500 mm isohyet.

Story (1952) discussed the ecology of *Acacia karroo* in detail. His conclusion, that the species is absent from areas where the average absolute minimum temperature of the coldest month is less than 20 °F (-7 °C), seems to be confirmed by its distribution pattern along the Upper Orange River, but his statement that the species is also absent where the precipation drops below 15 inches (381 mm) does not agree with the present findings. It may be significant in this respect that several ecotypes of *Acacia karroo* presumably occur in South Africa, which makes ecological generalisation rather difficult (cf. Ross, 1971).

Like *Acacia karroo, Ziziphus mucronata* is a widespread species in South Africa. It clearly has its optimal presence and cover-abundance in the Zizipho-Acacietum karroo, but it is found also as a differential species in two other syntaxa occurring away from the levees (cf. Chapters 5.4 and 5.5). It also occurs in wetter climates, for example in Natal, and it is therefore quite possible that several ecotypes of this species exist in South Africa.

On the outer edges of the levees, where the fine sandy alluvium is somewhat mixed with the loamy residual of the surroundings of the river-bed, a semi-open to dense scrub community dominated by *Salsola glabrescens* often occurs. As can be seen from **Table 5 the species** *Lycium arenicolum* and *Diospyros lycioides* subsp. *lycioides* of the Diospyrion lycioidis can also be abundant in this *Salsola glabrescens* Community, whereas species of the Pentzio-Chrysocomion intrude into this community as well.

The *Salsola glabrescens* Community is two layered: a shrub layer up to 2 m tall, and a ground layer up to 0,60 m high.

At various localities along the Upper Orange River, particularly where the alluvial soil deposits cover an area of over 100 m wide, the vegetation of

TABLE 5 - *Salsola glabrescens* Community

Relevé No.	169	18	63	561	559	560	
SL	30 ° 38'	30 ° 33'	30 ° 35'	30 ° 34'	29 ° 47'	29 ° 36'	
EL	26 ° 30'	25 ° 56'	25 ° 55'	29 ° 19'	24 ° 24'	24 ° 08'	Sociability
Total cover (%)	55	60	95	-	90	100	
Total No. of species	12	8	9	5	4	3	
Salsola glabrescens	2b	3	5	4	5	5	2-5
Lycium arenicolum	1	2a	+	2b	2a		2
Diospyros lycioides	+		2b	1		2a	1-2
Eragrostis lehmanniana	2a	2b	2b	+			2
Chrysocoma tenuifolia	+	+	+				1-2
Setaria verticillata					+	2a	2-3
Pentzia globosa		2a	3				1-2
Asparagus suaveolens		+	+				2

Also occurring in Relevé 169- *Osteospermum spinescens* (2b), *Felicia muricata* (2a), *Asparagus setaceus* (+), *Walafrida saxatilis* (+), *Convolvulus sagittatus* var. *ulosepalus* (+), *Cyperus usitatus* (+), *Lessertia pauciflora* (r); Relevé 18- *Tragus koelerioides* (+), *Enneapogon desvauxii* (+); Relevé 63- *Acacia karroo* (r), *Celtis africana* (r); Relevé 561- *Tetragonia arbuscula* (+); Relevé 559; *Tribulus terrestris* (3)

FIG. 25 - *Eragrostis lehmanniana - Asthenatherum glaucum* Community on alluvial-aeolian sand near Douglas. See also Table 7

TABLE 6 - *Stipagrostis namaquensis-Eragrostis lehmanniana* Community

Relevé No.	474	509
SL	29 ° 23'	29 ° 06'
EL	23 ° 55'	23 ° 42'
Total cover (%)	60	25
Total No. of species	4	10
Stipagrostis namaquensis	3.2	2b.2
Eragrostis lehmanniana	2b.2	1.2
Stipagrostis obtusa		1.2
Stipagrostis ciliata		+.2
Aristida congesta		+.2
Tragus berteronianus		+.2
Eragrostis porosa		+.2
Orthanthera jasminiflora		+.1
Hirpicium echinus		+.2
Chenopodium schradianum	+.2	
Pentzia calcarea	+.1	
Phaeoptilum spinosum		r

TABLE 5.1.4 - *Eragrostis lehmanniana-Asthenatherum glaucum* Community

Relevé No.	504
SL	29 ° 06'
EL	23 ° 38'
Total cover (%)	20
Total No. of species	10
Eragrostis lehmanniana	2a.2
Asthenatherum glaucum	+.2
Stipagrostis obtusa	2a.2
Stipagrostis ciliata	+.2
Eragrostis brizantha	+.2
Helichrysum arenicola	+.2
Orthanthera jasminiflora	+.1
Tribulus zeyheri	+.2
Limeum fenestratum	+.1
Celosia linearis	+.2

the Diospyrion lycioidis and the *Salsola glabrescens* Community has been cleared and the land is under cultivation (cf. Chapter 2.7.).

Sand accumulations of considerable extent, probably of mixed alluvial and aeolian origin, occur in the vicinity of Douglas (cf. Chapter 2.5.). On deep sandy semi-stabilized dunes in that area a *Stipagrostis namaquensis - Eragrostis lehmanniana* Community occurs and physiognomically this strongly resembles the Stipagrostietum amabilis Leistner et Werger 1973 of the dune crests of the southern Kalahari. This is largely due to the strong physiognomic resemblances between *Stipagrostis namaquensis* and *S. amabilis*. Also in floristic composition the two communities show similarities as can be seen from Table 6 as well as from Table 2 in Leistner & Werger (1973). A related type of community is also described from alluvial sand at Augrabies in the Lower Orange River valley (Werger & Coetzee, 1977). The grass tussocks can be up to 1,80 m tall.

In the same area an extensive flat plain of alluvial-aeolian sand occurs on which an *Eragrostis lehmanniana-Asthenatherum glaucum* Community is found which is floristically closely related to the Hirpicio echini - Asthenatheretum Leistner et Werger 1973 of the dune valleys of the southern Kalahari. **Relevé 504 (Table 7) (Fig. 25)** is an example of this community which consists of a single grass layer of up to 0,35 m high.

5.2 THE GRASSLAND COMMUNITIES OF THE EASTERN UPPER ORANGE RIVER VALLEY

(Table 8)

The entire eastern half of the South African plateau, comprising a large part of the Eastern Cape and the Orange Free State, is dominated by grassland vegetation. Although the precipitation in this area is such that according to Walter (1962) woody vegetation would be expected, regularly occurring frosts might be the cause of the complete absence of trees and large shrubs in all but sheltered sites. Acocks (1953) states that these regions "are too dry and/or too frosty for the development of any kind of forest. Only on rocky hills, which are rare on the plains, and on the mountains, will a few scattered shrubs be found".

Another factor of significant importance preventing the development of woody vegetation in these areas, is fire (Daubenmire, 1968b). Because numerous fires are reported to have been started by lightning and also by sparks generated when boulders collide while rolling downhill, fire certainly has to be regarded as a natural factor in the grassland areas of southern Africa (Bayer, 1955; Pienaar, 1956; Killick, 1963; Walter, 1968; Scott, 1970). So the question still remains unanswered: do the eastern plateau grassland areas constitute a zonal vegetation or is the vegetation pyrophilic (Walter, 1968)?

As mentioned in Chapter 2.6 (page 24), two veld types cover the grasslands of the Upper Orange River valley: the southern variation of the sandy *Cymbopogon-Themeda* Veld (Acocks's Veld Type 48) fringing the borders of Lesotho, and the southern variation of the dry *Cymbopogon-Themeda* Veld (Veld Type 50) which occurs in a narrow zone between the former (Type 48) and the False Upper Karoo (Type 36). A general account of the eastern grasslands is given by Bews (1918) in Clementsian terms.

Grasslands with *Themeda triandra* occur over extensive areas in Africa. Lebrun (1947) provisionally described the East African grasslands, in which *Themeda triandra* is dominant or frequent, under the name Themedetalia triandrae. The character species for this order, as listed by him and by Taton (1948), do not occur in the grassland communities of the South African Highveld, however, and it is thus likely that these communities do not belong to the same order as the East African ones. Volk & Leippert (1971), discussing a *Themeda* community from South West Africa, used the class name Themedetea, which is a nomen nudum, since the authors do not indicate which syntaxa are meant to be incorporated in this class.

The exact syntaxonomical position of the grasslands in the eastern part of the Upper Orange River catchment area cannot be established at present.

In the present study only 24 relevés were sampled in the grassland vegetation. As shown by Table 8 three communities and two subcommunities could clearly be distinguished. However, for two reasons no attempt has been made to classify these communities into a formal phytosociological system. Firstly, the grassland area covered in this study represents only a very small fraction of the entire eastern-plateau grasslands which are closely related floristically (Fig. 26). Thus, only a small fraction of the floristic variation in these grasslands was sampled and a phytosociological classification based on such a limited sample cannot be expected to be scientifically accurate. Secondly, comprehensive plant ecological studies have been undertaken in recent years in various parts of this grassland region, the results of which are being worked on at present (Scheepers, 1975; Morris, 1973). These studies can be expected to result in scientifically more reliable and more applicable classifications, into which the results provided here can be incorporated.

The *Brachiaria serrata - Elionurus argenteus* Community occurs on sites mainly in the area covered by the sandy *Cymbopogon-Themeda* Veld (Acocks, 1953) (Fig. 27), which are not too severely overgrazed and trampled. The community is usually found on somewhat deeper pseudopodzolic soils, over 0,50 m deep, with a slightly acid topsoil of loamy sand on nearly horizontal layers of Molteno sandstones (cf. Chapter 2.5). Sometimes it was also encountered on shallow lithosols on south-facing

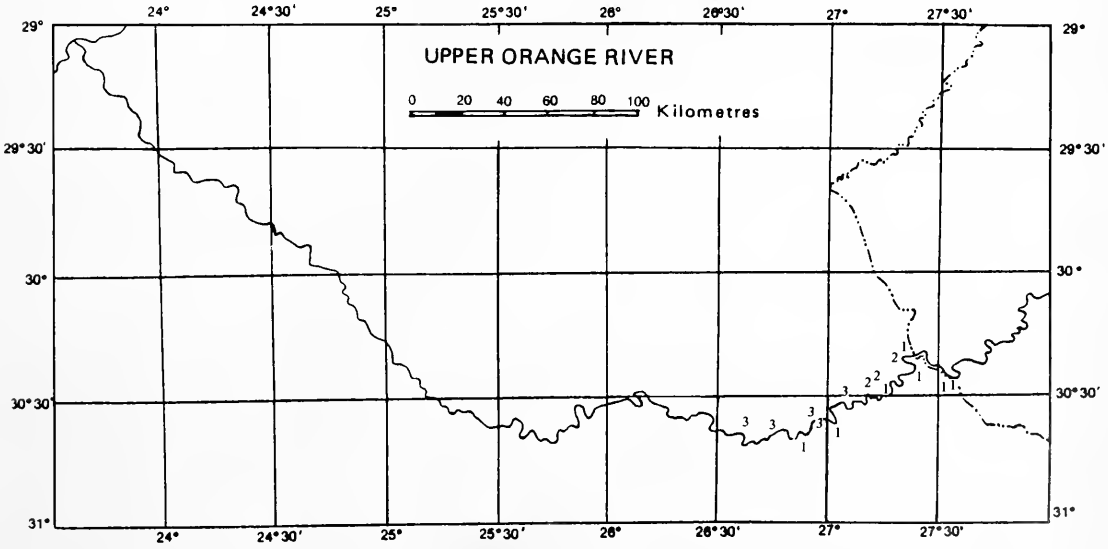


FIG. 26 - Distribution of eastern grassland communities in the Upper Orange River area. 1. *Brachiaria serrata - Elionurus argenteus* Community; 2. *Eragrostis plana - Eragrostis gummiflua* Community; 3. *Pentzia globosa - Eragrostis curvula* Community

FIG. 27 - *Brachiaria serrata* - *Elionurus argenteus* Community near Lady Grey. In background badly developed Rhoo-Aloetum ferocis. In middle distance *Diospyros lycioides* subsp. *lycioides*

FIG. 28 - *Eragrostis plana* - *Eragrostis gummiflua* Community between Aliwal North and Lady Grey. In background Rhamno-Rhoetum

slopes of 8° to 17° (relevés 239, 251). Species positively differentiating this community from the two others are the grasses *Brachiaria serrata, Elionurus argenteus, Hyparrhenia hirta, Eragrostis racemosa, Cymbopogon excavatus* and *Helictotrichon longifolium* and the forbs *Anthospermum rigidum, Helichrysum niveum, Dianthus basuticus* subsp. *basuticus, Helichrysum caespititium, Ajuga ophrydis, Dicoma anomala, Helichrysum rugulosum, Haplocarpha scaposa, Euphorbia striata* and *Senecio erubescens*. Other species of importance in this community are the grasses *Aristida diffusa* var. *burkei, Eragrostis curvula, Heteropogon contortus* and *Cymbopogon plurinodis* (Table 8).

Apart from the vegetation in relevé 257, this community consists of virtually one layer of grasses and forbs, up to 0,60 m in height, with an average cover of 75%. Prostrate, trailing and very low plants are so rare that they do not constitute a

FIG. 29 - Close-up of *Eragrostis plana - Eragrostis gummiflua* Community at relevé 234

separate vegetation layer. In relevé 257 the shrub *Euryops annae* is co-dominant. This shrub is avoided by sheep and shows a vigorous growth after heavy overgrazing of the veld. It is evergreen and can be up to 2 m tall.

Some of the association analysis end groups of Roberts's study of Thaba 'Nchu (1966), particularly end group 4, show strong floristic affinities with the *Brachiaria serrata - Elionurus argenteus* Community, and it is possible that the same community occurs in the Upper Orange River valley and at Thaba 'Nchu.

On damp sites with a deep soil of loamy sand, usually in slight depressions on gentle slopes or plains of Molteno sandstone, upstream from Aliwal North, the *Eragrostis plana - Eragrostis gummiflua* Community occurs (Figs 26, 28 and 29). Cattle and sheep often concentrate on such places with the result that these sites are heavily trampled. The community can be divided into two subcommunities: the *Eragrostis plana - Themeda triandra* Subcommunity on the most loamy sites, which are not too heavily trampled, and the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity on the sandier and more heavily trampled bottomlands. The *Eragrostis plana - Eragrostis gummiflua* Community is floristically positively differentiated from the other grassland communities by *Eragrostis plana* and *Walafrida densiflora*. *Eragrostis plana* is very abundant in this community. Other species of importance are *Eragrostis curvula* and *Cymbopogon plurinodis*.

The two subcommunities differ floristically from one another in that *Themeda triandra* and *Panicum stapfianum* occur in the *Eragrostis plana - Themeda triandra* Subcommunity, but are lacking in the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity. In the latter subcommunity *Eragrostis gummiflua, Pentzia globosa, Cyperus usitatus, Helichrysum dregeanum, Aristida congesta, Euryops annae* and *Eragrostis lehmanniana* occur, whereas all of these species are absent from the *Eragrostis plana - Themeda triandra* Subcommunity (Table 8).

Except for relevé 244, where *Euryops annae* is important, the structure of the *Eragrostis plana - Eragrostis gummiflua* Community is similar to that of the *Brachiaria serrata - Elionurus argenteus* Community. In the *Eragrostis plana - Themeda triandra* Subcommunity the average total cover is much higher however, with values of 95 to 100 %. In the *Eragrostis plana - Eragrostis lehmanniana* Subcommunity total cover values average 65 %.

In the vicinity of Aliwal North, where the False Upper Karoo merges into the grassland vegetation, another grassland community occurs, the *Pentzia globosa - Eragrostis curvula* Community (Figs 26 and 30). It is found on slightly acid loamy sands and sandy loams, over 0,25 m deep, on level to slightly sloping Molteno and Beaufort sandstones. These sites have all been moderately to severely overgrazed and erosion, particularly sheet erosion, is common. The following species, of which many are Pentzio-Chrysocomion species (cf. Chapter 5.3), differentiate positively between this community and the other grassland communities: the dwarf shrubs *Pentzia globosa, Chrysocoma tenuifolia, Felicia muricata* and *Pterothrix spinescens*, the grasses *Eragrostis obtusa, Tragus koelerioides* and *Sporobolus fimbriatus*, the forbs *Hermannia coccocarpa, Listia heterophylla* and *Solanum supinum* and the sedge *Kyllinga alba*. Other important species in this community are *Eragrostis curvula, Themeda triandra, Aristida congesta, Digitaria eriantha* and *Euryops annae*. The last-named species again indicates the severity of overgrazing in this community. The floristic composition of the *Pentzia globosa - Eragrostis curvula* Community compared with the other two grassland communities discussed, shows clearly that it occurs in a drier environment than the other two. Species indicating this are particularly the Pentzio - Chrysocomion species such as *Pentzia globosa, Chrysocoma tenuifolia, Eragrostis obtusa, Tragus koelerioides, Aristida congesta* and others (Table 8).

The *Pentzia globosa - Eragrostis curvula* Community can consist of three layers. The most heavily overgrazed patches have a shrub layer of *Euryops annae*, between 1 and 2 m tall, covering 20 to 25 %. There is always a dwarf shrub and grass layer, in which grasses are usually dominant, up to 0,70 m in height, and covering between 20 and 50 % in the phases with *Euryops annae*, but up to 95 % in the other stands. Sometimes there is a

FIG. 30 - *Pentzia globosa - Eragrostis curvula* Community on overgrazed site near Lady Grey. At some stands dwarf shrubs can be more abundant than on this picture

ground-layer of plants up to 0,05 m high, whose cover can reach a value of up to 15 %.

The communities discussed under the name "*Themeda*-veld" by Mostert (1958) show a considerable degree of similarity with the *Pentzia globosa - Eragrostis curvula* Community, but the phases with *Euryops annae* do not occur in Mostert's study area north of Bloemfontein.

Gazania krebsiana, Aristida diffusa var. *burkei* and *Convolvulus boedeckerianus* are common to the *Brachiaria serrata - Elionurus argenteus* Community and the *Pentzia globosa - Eragrostis curvula* Community, whereas they are virtually absent from the *Eragrostis plana - Eragrostis gummiflua* Community. Common to the latter and to the *Pentzia globosa - Eragrostis curvula* Community and absent from the *Brachiaria serrata - Elionurus argenteus* Community are *Cyperus usitatus* and *Sporobolus fimbriatus,* whereas *Eragrostis capensis* is common to the *Brachiaria serrata - Elionurus argenteus* and the *Eragrostis plana - Eragrostis gummiflua* Communities, but virtually absent from the *Pentzia globosa - Eragrostis curvula* Community.

Of the species common to all three communities *Eragrostis curvula, Themeda triandra, Helichrysum dregeanum, Aristida congesta, Heteropogon contortus, Cymbopogon plurinodis, Walafrida saxatilis, Hermannia depressa, Sutera aurantiaca* and *Setaria flabellata* are the most constant (Table 8).

In a rigid analysis of species/habitat associations, Roberts (1971) investigated habitat preferences for a number of grass species occurring in the grassland communities described above. Data were collected at Thaba 'Nchu. From the results some indication on the autecology of certain species might be obtained, although, due to the rigid and arbitrary definition of the habitat categories, the results should be interpreted carefully. Roberts (1971) found, for example, a positive association between slope angle of 0 ° to 5 ° and a low degree of stoniness and the occurrence of *Eragrostis plana,* and between sloping sites with angles from 6 ° to 30 ° and the occurrence of *Brachiaria serrata* . The latter species was also found to be associated with stoniness of the soil, a low degree of erosion and trampling and a sandy soil. *Tragus koelerioides* was found to be associated with, amongst others, a medium degree of erosion and a high degree of trampling. These and other results of Roberts (1971) agree reasonably well with the above outline of the habitats on which the grassland communities in the Upper Orange River valley occur.

5.3 THE COMMUNITIES OF THE PLAINS OF THE FALSE UPPER KAROO (PENTZIO-CHRYSOCOMION prov.)

(Table 9)

The pediplains between the mesas, koppies and ridges in the wide stretch of land from Aliwal North to Petrusville, bear a largely uniform vegetation of dwarf shrub steppe. Soils are sandy

FIG. 31 - Open stand of Hermannio coccocarpae - Nestleretum confertae aptosimetosum marlothii near Norvalspont. Dwarf shrubs are mainly *Chrysocoma tenuifolia*

loams, usually more than 1 m deep and of the solonetzic type, particularly in the area east of Colesberg. The top soil is slightly acid, becoming alkaline in the B horizon (cf. Chapter 2.5). Sheet and gully erosion occur on a large scale.

The slope angle of the pediplains is usually between 0° and 3° and seldom measures as much as 7° (cf. Fair, 1948). The underlying substrate is formed by Beaufort sandstones, mudstones and rarely by shales.

As discussed in Chapter 2.6 this vegetation is a result of anthropogenic influences, particularly overgrazing by sheep and other forms of agricultural mismanagement. The vegetation is therefore floristically relatively poor and character species are not very constant. Hence, phytosociological characterization is more difficult than in the case of vegetation types that are not so poor in species due to anthropogenic influences.

Almost the entire vegetation of the plains in this area is constituted by one association, the Hermannio coccocarpae-Nestleretum confertae, with the following character and differential species: *Hermannia coccocarpa, Osteospermum scariosum, Convolvulus boedeckerianus, Lessertia pauciflora* (d), *Nestlera conferta, Schizoglossum capense* and *Cynodon hirsutus*. With the exception of *Nestlera conferta*, these species are inconspicuous and never dominant. *Nestlera conferta* is usually a bright green, compact, prostrate dwarf shrub. The association is subdivided into three subassociations (Table 9).

On the somewhat sandier sites, often fringing the pediment slopes, where sheet erosion is a common phenomenon, the subassociation aptosimetosum marlothii occurs (Fig. 31). Differential for this subassociation are the dwarf shrubs *Aptosimum marlothii* and *Eriocephalus spinescens* and the grass *Enneapogon desvauxii*. Acocks (1953) lists *Aptosimum marlothii* as an Arid Karoo species intruding the False Upper Karoo. The subassociation is encountered mainly in the area between Colesberg and Petrusville, possibly because the soil is more often sandier in this area as a result of a slight influence of Kalahari sand deposition that finds its southeastern-most extension here (Fig. 32).

Between Aliwal North and Colesberg, particularly between Aliwal North and Bethulie, the subassociation eragrostietosum curvulae is found frequently (Figs 32 and 33). It is typified by the differential species *Eragrostis curvula, Cyperus usitatus, Themeda triandra, Helichrysum dregeanum* and *Solanum supinum*. The dwarf shrub *Pentzia globosa* reaches constantly high cover-abundance values in this subassociation, whereas *Gazania krebsiana* occurs only infrequently. This subassociation seems to be the most typical form of the association, because *Eragrostis curvula* and *Themeda triandra*, which are regarded as relict species of the former grassland vegetation, are among the differential species of the subassociation, and because this subassociation covers the largest area by far. *Eragrostis curvula* and *Themeda triandra* appear to establish themselves easily from seed, and are most abundant on sites that are not so heavily overgrazed and trampled, or that have been withdrawn from grazing for some time. Except for *Cyperus usitatus*, the differential species of the eragrostietosum curvulae are all common in the Rhoetea erosae communities (cf. Chapter 5.4).

On sites on the plains east of Colesberg that are quite strongly eroded and where the remaining top soil is a very hard compact loam, a third community occurs, the oropetietosum, with the diminutive grass *Oropetium capense* as differential species (Figs 32 and 34). This species is one of the few grasses reported to withstand extreme desiccation (Gaff, 1971; Gaff & Ellis, 1974). *Oropetium capense* was also found to be typical of some of the more compact soils in the southern Kalahari (Leistner & Werger, 1973).

A variant with *Eragrostis lehmanniana* of the Hermannio coccocarpae-Nestleretum confertae, which cannot be placed unequivocally into one of

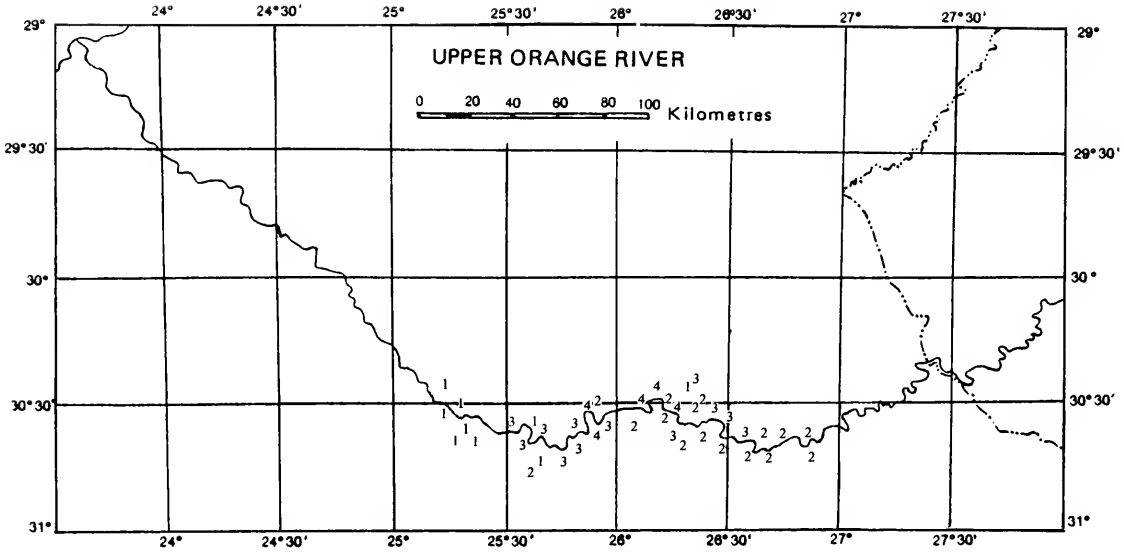


FIG. 32 - Distribution of Hermannio coccocarpae - Nestleretum confertae in the Upper Orange River area. 1. aptosimetosum marlothii; 2. eragrostietosum curvulae; 3. oropetietosum; 4. *Eragrostis lehmanniana* - variant

the subassociations, also occurs in the Upper Orange River area (Fig. 32). It is found on sites that were ploughed several years ago and have been left unused, and on badly eroded places that have since been withdrawn from grazing for a number of years and are now recovering. This variant is usually very poor in species, and *Eragrostis lehmanniana* scores constantly high cover values.

It is probable that in the same region but outside the study area, floristically related communities occur, and possibly some of the minor communities described in Chapter 5.7 are related to the Hermannio coccocarpae-Nestleretum confertae. Although no complete syntaxonomic hierarchy can be described at present, it is likely that the Hermannio coccocarpae-Nestleretum confertae

FIG. 33 - Hermannio coccocarpae - Nestleretum confertae eragrostietosum curvulae near Goedemoed. Termite heaps are abundant. The dominant species is *Chrysocoma tenuifolia*

FIG. 34 - Donovan's Kop near Bethulie on which Stachyo-Rhoetum occurs. In foreground Hermannio coccocarpae - Nestleretum confertae oropetietosum

together with some related communities, constitute an alliance, the Pentzio-Chrysocomion (prov.). This alliance would probably stand on its own and its character species would at the same time be the character species for the order, Pentzio-Chrysocometalia (prov.), and the class, Pentzio-Chrysocometea (prov.). These species would be the wide-spread "Karoo pioneers", which have their optimal presence or cover-abundance in the Pentzio-Chrysocomion communities. They are the dwarf shrubs *Chrysocoma tenuifolia, Pentzia globosa, Walafrida saxatilis, Lycium salinicolum* (which can also occur as a low shrub), *Gnidia polycephala, Felicia muricata, Pterothrix spinescens* and *Hermannia linearifolia,* the grasses *Tragus koelerioides, Eragrostis lehmanniana, Aristida congesta* and *Eragrostis obtusa,* the prostrate forb *Indigofera alternans* and the low rosette plants *Gazania krebsiana* and *Mariscus capensis.* In the text and in the tables they are listed as Pentzio-Chrysocomion species.

Most of the dwarf shrubs are gray or brownish microphyllous "evergreens", giving the Karoo vegetation its marked "dead" appearance. They can withstand long periods of drought, owing to their low transpiration, the high osmotic pressure of their cell sap, and their small leaf surfaces (Henrici, 1940; Walter, 1962). The osmotic pressure is highest, when the soil moisture content is lowest (compare also Aaltonen, 1923). It was shown by Roux (1966) that rains falling late in the growing season invigorate the growth of dwarf shrubs, contrary to rains falling early in the growing season which stimulate the grass growth in this vegetation. A number of species of the Rhoetea erosae communities occur as accompanying species in the Hermannio coccocarpae-Nestleretum confertae. Most frequent of these are *Aristida diffusa* var. *burkei, Nenax microphylla, Limeum aethiopicum, Aptosimum depressum, Hibiscus marlothianus, Trichodiadema pomeridianum* and *Hibiscus pusillus.* In his account of the plant communities of Tussen die Riviere Game Farm, O.F.S., Werger (1973a) gave a preliminary description, based on a small number of samples, of the Hermannio coccocarpae-Nestleretum confertae, under the provisional name *Chrysocoma tenuifolia - Lessertia pauciflora* Community. The association was not yet subdivided into subassociations. The variant with *Eragrostis lehmanniana* of the Hermannio coccocarpae-Nestleretum confertae was described as the *Eragrostis lehmanniana - Chrysocoma tenuifolia* Community, in Werger's account.

All the subassociations and the variant of the Hermannio coccocarpae-Nestleretum confertae are generally two-layered: a dwarf shrub and grass layer of 0,35 to 0,50 m high, and a ground layer of very short plants, up to 0,08 m high. In the aptosimetosum marlothii the uppermost layer covers between 10 and 25 % on the average, and in exceptional cases up to 50 %, whereas the ground layer rarely covers more than 10%. In the eragrostietosum curvulae the layer of dwarf shrubs and grasses covers between 35 and 70 %, and the ground layer usually 5 %, but occasionally up to 20% of the surface. In the oropetietosum the percentages of cover of both layers vary widely. The range in cover-values of the uppermost layer is from 15 to 80 %, and that of the ground layer from 5 to 30 %. The variant with *Eragrostis lehmanniana* always scores high cover values of between 50 and 70 % for the uppermost layer, but the ground layer rarely covers more than 5 %.

5.4 THE SHRUB COMMUNITIES OF THE EASTERN GRASSLAND AREA AND THE FALSE UPPER KAROO (RHOETEA EROSAE)

5.4.1 Introduction

In this chapter the multistratal shrubby communities occurring on the sloping terrain in the eastern grassland area, on the sandy and dry *Cymbopogon - Themeda* Veld (Acocks, 1953, Veld Types 48 and 50), and in the False Upper Karoo (Acocks, 1953, Veld Type 36) are discussed. These communities have strong floristic similarities and belong to the class Rhoetea erosae. The floristic similarities shown by these hillside communities of the three Veld Types are perhaps a strong argument for the thesis that before the colonization by white sheep farmers just over a century ago, the False Upper Karoo was also a *Cymbopogon - Themeda* grassland (cf. Chapter 2.6).

The following syntaxa are discussed in this chapter (the code in front of the syntaxa names symbolizes the relationships between the syntaxa):

1	Rhoetea erosae
1A	Grewio-Rhoetalia erosae
1A1	Indigofero spinescentis-Rhoion erosae
1A1a	Rhamno-Rhoetum
1A1b	Rhoo-Aloetum ferocis
1A2a	Blepharido-Rhoetum
1B	Rhoetalia ciliato-erosae
1B1	Hibisco marlothiani-Rhoion erosae
1B1a	Osteospermetum leptolobi
(1)	typicum
(2)	aptosimetosum marlothii
1B1b	Stachyo-Rhoetum
(1)	polygaletosum
(2)	hermannietosum vestidae
(2a)	*Salvia namaensis*-variant
1B1c	Nanantho vittati-Rhoetum
1B2a	Mayteno polyacanthae-Oleetum africanae
(1)	typicum
(2)	chamareetosum
1B3a	Setario lindenbergianae-Buddlejetum salignae

5.4.2 The shrub communities of mesic sites (Grewio-Rhoetalia erosae) (Table 10)

The area between Aliwal North and the South African-Lesotho border is characterized by relatively strong relief (Figs 3 and 8). The Orange River has cut a deep trough mainly through hard Molteno sandstones and the countryside further away from the river-bed is also relatively strongly dissected. The soils on the hill and mountain-sides in this area are mainly shallow, neutral to slightly acid lithosols. Within the boundaries of South Africa this part of the Upper Orange River valley receives the most precipitation, while the lowest temperatures are recorded. The climate may be typified as subhumid warm temperate (cf. Chapter 2.2.8). On the plains and on some slopes in this area grassland communities which were discussed in Chapter 5.2, occur. On the steeper slopes, however, shrubby communities occur, which are generally rich in species.

The Rhamno-Rhoetum (Fig. 35) occurs on steep Molteno sandstone slopes of nearly always over 15° with a southerly aspect and mainly south or south-east facing. Relevés 241 and 267 (Table 10) were recorded on northerly facing slopes, but were so situated that they were protected by surrounding mountains from influences usually associated with northerly facing sites. The Rhamno-Rhoetum is characterized by a large number of character species and by differential species against the other associations of the Grewio-Rhoetalia erosae and against several other associations of the Rhoetea erosae. Shrub and small trees amongst these species are *Myrsine africana, Rhamnus prinoides, Asparagus denudatus, Rhus dentata, R. divaricata, Halleria lucida, Cliffortia linearifolia* (d), *Cussonia paniculata,* the climber *Clematis brachiata* (d), *Tarchonanthus camphoratus* (d), *Kiggelaria africana* and *Heteromorpha arborescens.* Grasses are *Helictotrichon longifolium, Pentaschistis setifolia* (d), *Koeleria cristata* (d), *Cymbopogon validus, Harpochloa falx* (d) and *Festuca scabra* (d), and further character and differential species occurring in the lowest layers are *Helichrysum odoratissimum, H. nudifolium* (d), *Vernonia capensis, Hypericum aethiopicum, Carex spicato-paniculata, Crassula schimperi* var. *lanceolata, C. harveyi, Haplocarpha scaposa* (d), *Senecio latifolius, Stachys aethiopica, Kobresia sparteum, Delosperma concavum, Scabiosa columbaria* (d), *Lactuca capensis* (d), *Artemisia afra* (d), *Dimorphotheca cuneata, Pellaea quadripinnata* and *Satureja biflora.* Some other species also often score high cover-abundance values in this association. They are the shrubs and trees *Felicia filifolia,* (often regarded as an indicator of overgrazing), *Osyris lanceolata, Clutia pulchella, Rhus erosa, R. undulata* var. *tricrenata, Diospyros lycioides* subsp. *lycioides, D. austro-africana, Olea africana* and a few others (Table 10).

As the above list of species and Table 10 show, the Afro-montane element is well represented in this association. Several of the species encountered in this association, or their closest allies, are found in the montane zone throughout eastern Africa and also occur scattered in temperate Europe and Asia, particularly in the Himalayas (Hedberg, 1965; Chapman & White, 1971).

The association usually occurs as a rather dense scrub. Total aerial cover of the stands of the association is usually between 65 and 70%. Layers are not always clearly distinct from one another, but it is often possible to separate a shrub and small tree layer, covering between 40 and 50%, from a ground-layer covering between 20 and 30%, the former varying in height from 1,0 to 3,5 m and even as high as 5 m, and the latter varying from 0,70 m to 1 m in height. Relevés 268, 270 and particularly 269 and 267, sampled in the Herschel

District, were very heavily overgrazed and trampled by goats and do not represent typical examples of this association, either in floristics or in structure. Relevés 206, 556, 536 are floristically atypical. They represent isolated phytocoenoses situated considerably further westwards in the drier False Upper Karoo, away from the main distribution area of the association.

In an association analysis of the vegetation of Thaba 'Nchu, a flat-topped mountain approximately 80 km east of Bloemfontein, Roberts (1966) arrived at 28 end-groups of the dichotomy, which he called communities. Data for the association analysis were collected systematically, using 4 × 4 m samples in bush. Only presence or absence data were used in the computation. The results of such a study are difficult to correlate with those of a floristic analysis of the present type. From Roberts's short descriptions of his rigidly determined "communities" it is apparent, however, that some of the end-groups are probably identical with the presently described Rhamno-Rhoetum. In particular his end-groups 14 (*Euclea-Felicia filifolia* Scrub) and 15 (*Euclea-Clutia* Bush) might belong

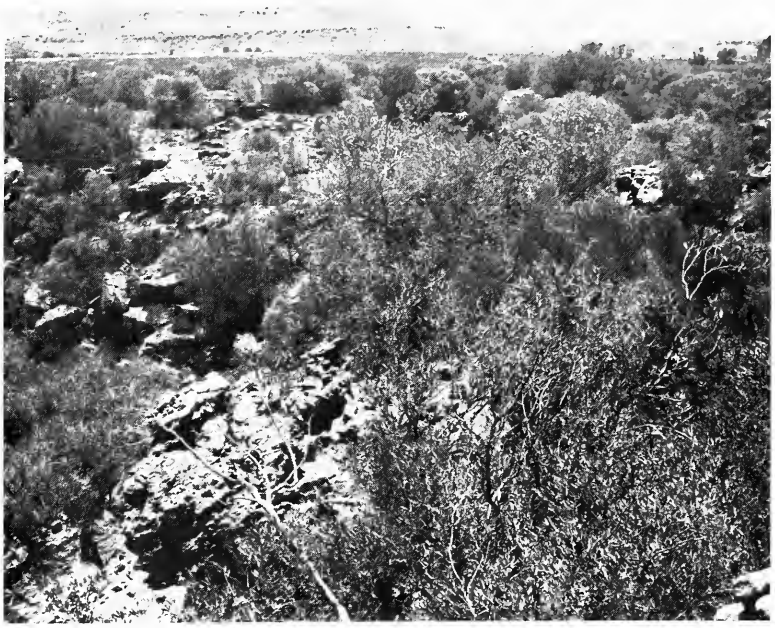


FIG. 35 - Rhamno - Rhoetum on steep, rocky valley side of Upper Orange River between Aliwal North and Lady Grey. *Olea africana* and *Celtis africana* can be seen in the foreground

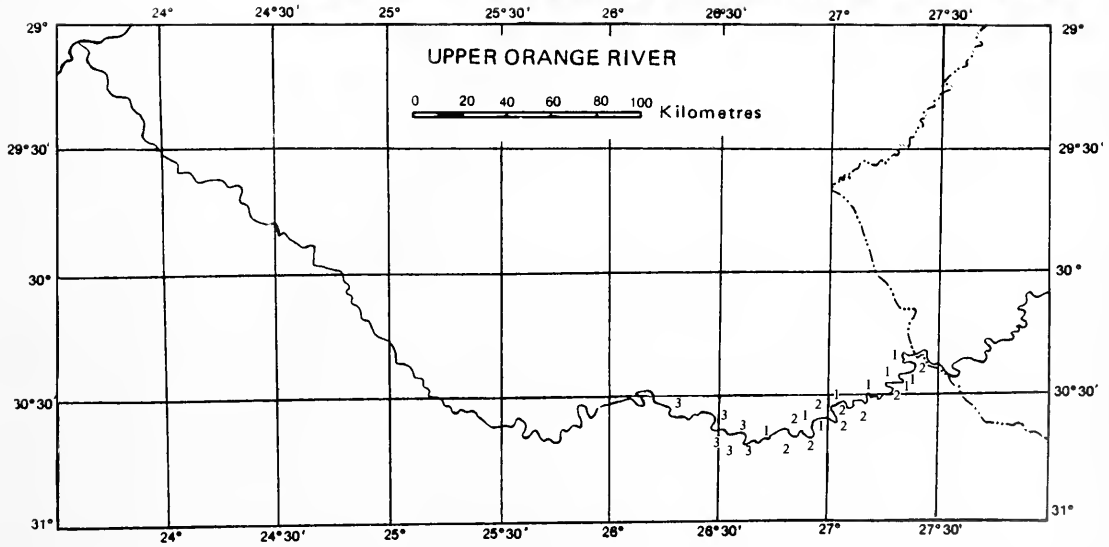


FIG. 36 - Distribution of Grewio - Rhoetalia erosae in the Upper Orange River area. 1. Rhamno - Rhoetum; 2. Rhoo - Aloetum ferocis; 3. Blepharido - Rhoetum

to the Rhamno-Rhoetum. It is interesting in this context that Roberts found a highly significant positive association between end-group 14 and slopes of Molteno sandstones. The correlation between the Rhamno-Rhoetum and Roberts's end-group 14 and Molteno sandstone is possibly more a matter of the occurrence at the same high altitudes where the Molteno sandstone stratum emerges.

In the same area where the Rhamno-Rhoetum occurs, the Rhoo-Aloetum ferocis is found (Figs 36, 37 and 38). The latter occurs mainly on Molteno sandstones, but occasionally on Red Beds, and Beaufort and doleritic substrates as well. It is encountered on neutral to slightly acid lithosols on steep slopes but, in contrast to the habitat of the Rhamno-Rhoetum, the slopes where the Rhoo-Aloetum ferocis occurs are northerly facing. The Rhoo-Aloetum ferocis is a shrubby community that is characterized by the following character species and differential species as against the other Grewio-Rhoetalia erosae communities: the liliaceous succulent, tree-like *Aloe ferox,* the shrubs *Asparagus virgatus, Hermannia cuneifolia* var. *glabrescens* (d) and *Ehretia rigida* (d), the climber *Antizoma angustifolia* and the ground-layer species

FIG. 37 - Rhoo - Aloetum ferocis near Mayaputi bridge south of Zastron. Recognizable species include *Aloe ferox, Olea africana, Rhus erosa, Rhus undulata* and *Hyparrhenia hirta.* In foreground *Eragrostis plana - Eragrostis gummiflua* Community

FIG. 38 - Rhoo-Aloetum ferocis between Aliwal North and Lady Grey with *Aloe ferox, Diospyros lycioides* subsp. *lycioides* and *Rhus erosa*

Rhynchelytrum repens (d), *Pavonia burchellii, Aristida bipartita, Crassula cooperi, C. schimperi* var. *schimperi, Brachystelma* sp. and *Cotyledon orbiculata-decussata* complex (d). As in the Rhamno-Rhoetum, woody species such as *Felicia filifolia, Osyris lanceolata, Clutia pulchella, Rhus erosa, R. undulata* var. *tricrenata, Diospyros lycioides* subsp. *lycioides, D. austro-africana, Olea africana* and a few others can be important. The shrub *Indigofera spinescens* is also often abundant (Table 10).

Aloe ferox finds its furthest inland distribution in this area and serves as a constant character species. The considerable number of succulents amongst the character and differential species of the Rhoo-Aloetum ferocis suggest that the northerly slopes, which are typical for the association, involve a much hotter and drier habitat than the mesic southerly slopes on which the Rhamno-Rhoetum occurs. Also species like *Eustachys mutica, Enneapogon scoparius, Asparagus suaveolens, Lantana rugosa* and several others, which are commonly found in the drier False Upper Karoo area and which positively differentiate between the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum on the one hand and the Rhamno-Rhoetum on the other, illustrate this point.

The Rhoo-Aloetum ferocis is an open shrub community. The shrub layer, with *Aloe ferox* included, usually covers between 25 and 45%, and is commonly between 1 and 4 m high. Occasionally a very open tree layer of *Olea africana,* 6 to 7 m high, occurs. The cover of the ground layer which is up to 0,75 m high, varies considerably. Total aerial cover of the vegetation is 55% on the average, but varies between 35 and 75%.

Some of the relevés taken in the Herschel District are structurally not typical since they had been heavily overgrazed by goats and the woody elements in the vegetation are often felled for fuel to a considerable extent by the local population. Relevé 265 is further floristically atypical because it is situated on a less steep slope. Relevés 218 and 219 are floristically slightly different from the other stands of the association, probably owing to their situation on a south-easterly facing slope at the opening of the narrow valley trough of the Orange River towards the more open country near Aliwal North. Relevé 245 is clearly transitional between the Rhamno-Rhoetum and the Rhoo-Aloetum ferocis.

The Rhamno-Rhoetum and the Rhoo-Aloetum ferocis have a number of species in common, which are absent from all other communities of the Rhoetea erosae. They are accordingly combined into the alliance Indigofero spinescentis-Rhoion erosae, which has the following character and differential species: the shrubs *Indigofera spinescens, Felicia filifolia* (d), *Osyris lanceolata* (d) which also occurs in the Setario lindenbergianae-Buddlejetum salignae (see below), *Clutia pulchella, Asparagus laricinus* (d), *Euryops annae* (d) and *Ochna serrulata,* the grasses

FIG. 39 - Blepharido - Rhoetum near Aliwal North, with *Euphorbia aggregata, Aloe broomii* and *Olea africana*

Brachiaria serrata (d), *Setaria flabellata* (d), *Eragrostis racemosa* (d) and *Eragrostis capensis* (d), and the forbs *Sutera kraussiana, Hermannia quartiniana, Gerbera viridifolia* and *Athrixia angustissima.* The four grasses mentioned occur widespread over the higher rainfall areas of South Africa, whereas *Felicia filifolia* and *Euryops annae* are often indicators of overgrazing and mismanagement of the vegetation in the higher rainfall areas of the centre of South Africa. These six species differentiate positively, however, between the Indigofero spinescentis-Rhoion erosae and the other Rhoetea erosae communities (Table 10).

In the area around Aliwal North, where the grassland merges into the False Upper Karoo, and on protected sites between two close mountain ridges, or in narrow troughs as far west as Bethulie, another association that is floristically related to the Indigofero spinescentis-Rhoion erosae occurs, namely the Blepharido-Rhoetum (Figs 36 and 39). The association again occurs on steep slopes with a shallow, slightly acid to neutral lithosol, but does not seem to be associated with aspect or geological substrate. It has been recorded on Beaufort sandstones as well as on dolerite. The limiting habitat factors seem to be a complex of features resulting in a slightly mesic situation although less mesic than, or different from, the situation in which the Indigofero spinescentis-Rhoion erosae communities occur.

Character species and differential species of the Blepharido-Rhoetum against the Indigofero spinescentis-Rhoion erosae communities are *Blepharis integrifolia, Argyrolobium lanceolatum* (d), *Lycium salinicolum* (d), *Sutera halimifolia* (d), *Dianthus basuticus* subsp. *basuticus* (d), *Aloe broomii* (d), *Schizoglossum linifolium, Limeum aethiopicum* (d), *Senecio hieracioides* (d), *Mariscus capensis* (d) and probably *Euphorbia aggregata.* Several of these species also occur in other communities of the class Rhoetea erosae. The most important woody plants in the Blepharido-Rhoetum are *Rhus erosa* and *R. undulata* var. *tricrenata.* Some invading species of the Pentzio-Chrysocomion are constant in this association, but usually score only low cover-abundance ratings. The Blepharido-Rhoetum has a number of species in common with the Rhoo-Aloetum ferocis such as *Eustachys mutica, Enneapogon scoparius* and several others. These are mainly Rhoetea erosae species, but they are absent or virtually so from the Rhamno-Rhoetum, as has been mentioned above. Hence, they serve as positive differential species of the Blepharido-Rhoetum and the Rhoo-Aloetum ferocis as against the Rhamno-Rhoetum (Table 10).

The Blepharido-Rhoetum is usually two layered. Total cover averages about 55 %. There is a shrub and small tree layer, generally between 1 and 2,5 m high, but sometimes up to 4 m tall, covering about 30 % on the average, but occasionally up to 50 %. The ground layer is between 0,50 and 0,70 m high, and usually covers about 25 %.

A number of species are shared by the Indigofero spinescentis-Rhoion erosae communities and the Blepharido-Rhoetum and are lacking in the other Rhoetea erosae communities. Most of these species clearly indicate the more mesic situations required by these three Rhoetea erosae communities. Based on these floristic relationships, the Rhamno-Rhoetum, the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum are combined into the order Grewio-Rhoetalia erosae. The following species are characteristic or positively differential against the remainder of the Rhoetea erosae: the shrubs or small trees *Grewia occidentalis, Celtis africana* (d) and *Maytenus heterophylla,* the grasses *Elionurus argenteus* (d), *Hyparrhenia hirta* (d), *Melica decumbens* (d) and *Ehrharta erecta,* the forbs *Berkheya discolor, Rhynchosia totta, Hermannia depressa* (d), *Piloselloides hirsuta, Hibiscus aethiopicus, Polygala amatymbica* and the fern *Mohria caffrorum* (d) (Table 10).

A considerable number of other species which commonly occur, in and are regarded as typical for, most of the Rhoetea erosae communities, including the Grewio-Rhoetalia erosae, will be discussed below.

Hepburn's (1919) account of the plant communities in the Herschel District illustrates floristic relationships between some of his "mountain formation" and the Grewio-Rhoetalia, but not to such an extent that they can be identified as being the same. Although it is not possible to assess with certainty, the exact relationships of these communities with those from Potts & Tidmarsh's (1937) descriptive account of a local vegetation complex near Bloemfontein, it is clear that the community called by them "Koppie Bush" is floristically closely related to the Grewio-Rhoetalia erosae. Mostert's (1958) "Southeastern Slope-Community" is probably identical with Potts & Tidmarsh's "Koppie Bush", and the latter is pertinently the same as Müller's (1970) "Grewio-Buddleja-Sociation".

The floristic affinities shown by the *Euclea crispa-Ehrharta erecta* Association described from the ravines of the north-eastern Orange Free State by Van Zinderen Bakker Jr (1971), to the Grewio-Rhoetalia erosae are very limited and suggest no direct relationships.

5.4.3 The shrub communities of the False Upper Karoo (Rhoetalia ciliato - erosae)

(Table 11)

The plains of the False Upper Karoo bear a monotonous, floristically poor vegetation described in the previous chapter (5.3) under the name Pentzio-Chrysocomion. The vegetation of the numerous hillsides in the area is varied, however, and richer in species. Particularly the abundance and variety of grasses and the occurrence of shrubs and small trees cause the conspicuous difference in appearance between the vegetation of the plains and that of the slopes.

In the area between Aliwal North and Skurwekop, on gentle slopes (from 3° to 6° and

rarely up to 9°) where a shallow soil layer covers the underlying bedrock which generally consists of Beaufort sandstones and mudstones, the Osteospermetum leptolobi is encountered (Figs 40, 41 and 42). The soil is a sandy loam, usually only 0,05 to 0,10 m deep, which contains a large fraction of fine gravel and is always slightly acid, with a pH between 5,5 and 6,5. The association has the following character and differential species: the dwarf shrubs *Osteospermum leptolobum, Eriocephalus spinescens* (d), *Pentzia sphaerocephala, Phymaspermum parvifolium* and *Euryops empetrifolius,* which is less common. Another character species is *Euphorbia clavarioides*, which forms low but very compact, succulent cushions. Other species frequently encountered in this association are *Hibiscus marlothianus*, the prostrate woody plants *Aptosimum depressum* and *Nenax microphylla*, the grass *Aristida diffusa* var. *burkei* and the aizoaceous *Trichodiadema pomeridianum*. Also Pentzio-Chrysocomion species occur commonly and abundantly in the Osteospermetum leptolobi (Table 11).

On slightly sandier and somewhat deeper soils on the gentle slopes, particularly west of Colesberg, the subassociation Osteospermetum leptolobi aptosimetosum marlothii is found. Differential species for this subassociation as against the typical form of the association are the spinous dwarf shrub

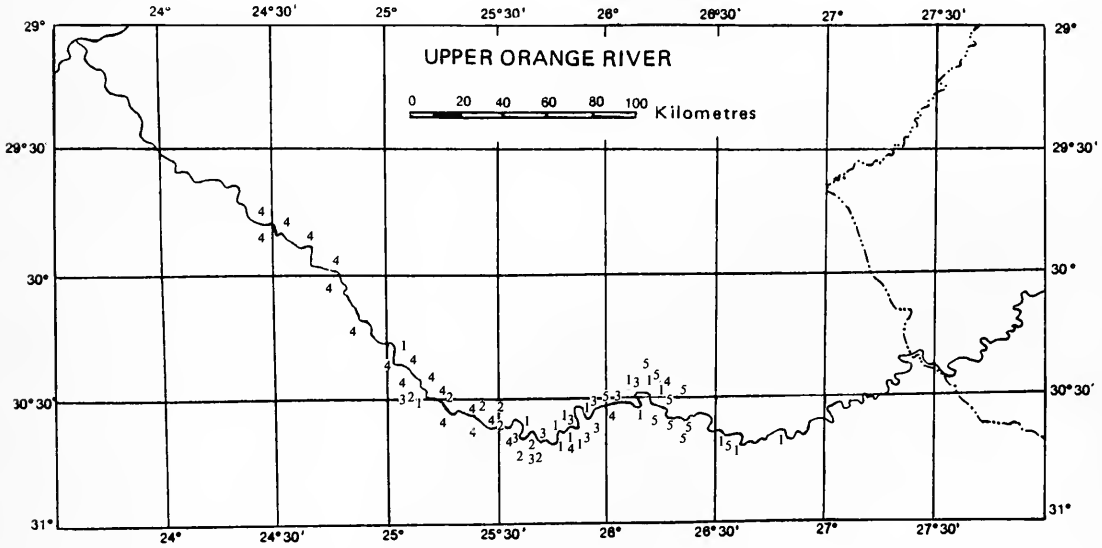


FIG. 40 - Distribution of Hibisco marlothiani - Rhoion erosea in the Upper Orange River area. 1. Osteospermetum leptolobi typicum; 2. Osteospermetum leptolobi aptosimetosum marlothii; 3. Stachyo - Rhoetum polygaletosum; 4. Stachyo - Rhoetum hermannietosum vestidae (*Salvia namaensis* - variant included); 5. Nanantho vittati - Rhoetum

FIG. 41 - Former view of Orange River between Norvalspont and Bethulie, now drowned by the waters of the Verwoerd Dam. In foreground Osteospermetum leptolobi typicum and along the river Rhoo -Diospyretum celtidetosum

Aptosimum marlothii, the small grass *Enneapogon desvauxii* and the slender dwarf shrub *Polygala leptophylla*. The aizoaceous dwarf shrub *Limeum aethiopicum* is remarkably constant in this subassociation (Table 11).

In both the typical form of the association and in the aptosimetosum marlothii, shrubs are not often encountered. It is generally a two-layered vegetation dominated by dwarf shrubs. Total cover for the typical form of the association amounts to 45% on the average, varying between 30 and 55%, whereas in the aptosimetosum marlothii the total cover averages 25%, varying between 10 and 35%. The dwarf shrub layer varies in height between 0,30 and 0,60 m and usually accounts for the total cover value. A ground layer of very low plants, up to 0,05 m in height, commonly covers only 5% or less, although values of 20% were sometimes recorded in the typical form of the association.

The association comprises the *Chrysocoma tenuifolia-Nenax microphylla* and *Chrysocoma tenuifolia-Polygala leptophylla* Communities preliminarily described from the vicinity of Bethulie by Werger (1973a).

On the steep hillsides, with slopes generally between 15° and 30°, where the bedrock consists of dolerite, or less frequently of Beaufort sandstones interrupted by dolerite layers, the Stachyo-Rhoetum is found. The association is common in the area between Aliwal North and Petrusville, but also occurs infrequently further downstream on the slopes of doleritic inselbergs rising up from the plains formed by Ecca deposits (Fig. 40). The association is mainly encountered on northerly facing slopes, although it might also occur on southerly facing slopes, which do not provide a mesic habitat. The soils on which the association is found are always shallow, loamy lithosols with a pH between 5,5 and 7,0.

FIG. 42 - Close-up of Osteospermetum leptolobi typicum near Norvalspont. Dwarf shrubs predominantly *Pentzia sphaerocephala* and *Osteospermum leptolobum*

The Stachyo-Rhoetum is characterized by the following character and differential species: the gray forb *Stachys rugosa* var. *linearis* (d), the grass *Fingerhuthia africana* (d), the dwarf shrubs *Phyllanthus maderaspatensis* (d) and *Indigofera sessilifolia* (d), and the slender forb *Heliophila suavissima*. Many other species occur in the association, of which *Pegolettia retrofracta, Limeum aethiopicum, Sutera albiflora, Rhus ciliata, Aristida diffusa* var. *burkei, Asparagus suaveolens, Heteropogon contortus, Rhus undulata* var. *tricrenata, R. erosa, Eustachys mutica* and several Pentzio-Chrysocomion species are amongst the commonest (Table 11).

Two subassociations of the Stachyo-Rhoetum have been distinguished. The polygaletosum occurs mainly in the area between Aliwal North and Colesberg on slopes with a predominantly coarse gravelly soil, usually derived from dolerite and Beaufort sandstone drift (Figs 40, 43 and 44). Positive differential species for this subassociation are *Polygala ephedroides* and *P. uncinata*.

In the area between Colesberg and Petrusville

FIG. 43 - Stachyo - Rhoetum polygaletosum on north-facing mudstone slope between Norvalspont and Venterstad. Recognizable shrubs include *Rhus erosa, Rhus undulata* and *Tarchonanthus camphoratus*

the hermannietosum vestidae is commonly encountered on dolerite (Figs 40, 45 and 46, Table 11). This subassociation is typified by a considerable number of differential species: the shrubs *Ehretia rigida, Rhigozum obovatum* and *Ziziphus mucronata*, the dwarf shrubs *Hermannia vestida, Polygala leptophylla, Barleria rigida, Hermannia pulchra,* and possibly *Aptosimum marlothii*, the succulents *Talinum caffrum, Pachypodium succulentum* and *Senecio longiflorus* and the grass *Eragrostis chloromelas*. The high cover-abundance values scored by *Rhus undulata* var. *tricrenata* in this subassociation are also typical, whereas *Rhus erosa* is relatively more important in the polygaletosum (Table 11). *Ziziphus mucronata* shows a reduced vitality in this subassociation compared with the riverine Zizipho-Acacietum karroo, in that it occurs always as a rather small shrub in the Stachyo-Rhoetum hermannietosum vestidae and never as a large tree as in the Zizipho-Acacietum karroo.

West of Petrusville, where the relief is less pronounced and only isolated doleritic inselbergs break the monotonous Ecca landscape, a variant with *Salvia namaensis* occurs, mainly on the middle and upper parts of steep, southerly facing slopes. The variant is typified by the forb *Salvia namaensis*, and the differential species of the

FIG. 44 - Stachyo - Rhoetum polygaletosum on north-facing mudstone slope between Norvalspont and Venterstad. In foreground Hermannio coccocarpae - Nestleretum confertae

hermannietosum vestidae also occur here, with the exception of *Polygala leptophylla, Pachypodium succulentum, Eragrostis chloromelas* and *Senecio longiflorus* (Table 11).

Four relevés (89, 16, 65 and 38) could not be placed in either of these subassociations.

The Stachyo-Rhoetum consists usually of three vegetation layers, to which may be added, in the polygaletosum and the hermannietosum vestidae, a very open layer of small trees of *Olea africana,* 5 to 6 m in height, covering up to 15 %. In the polygaletosum, a shrub layer up to approximately 2 m in height covering 10 % on the average, is always present. Further, there is a dwarf shrub and grass layer, measuring 0,50 to 0,60 m in height, with a range in cover from 20 to 75 %, and a ground layer of less than 0,05 m high, covering between 5 and 40 %. The average total cover of the subassociation amounts to 60 %.

In the hermannietosum vestidae the shrub layer is between 1 and 4 m high and usually covers 10 to 15 %, although values of 45 % are sometimes reached. The dwarf shrub and grass layer is 0,50 to 0,70 m high, covering between 20 and 35 % whereas the ground layer is up to 0,05 m high and usually covers less than 5 %. In the *Salvia namaensis*-variant the shrub layer also measures between 1 and 4 m in height, usually covering about 15 %. The dwarf shrub and grass layer is 0,80 m high, covering 35 to 40 % largely due to the

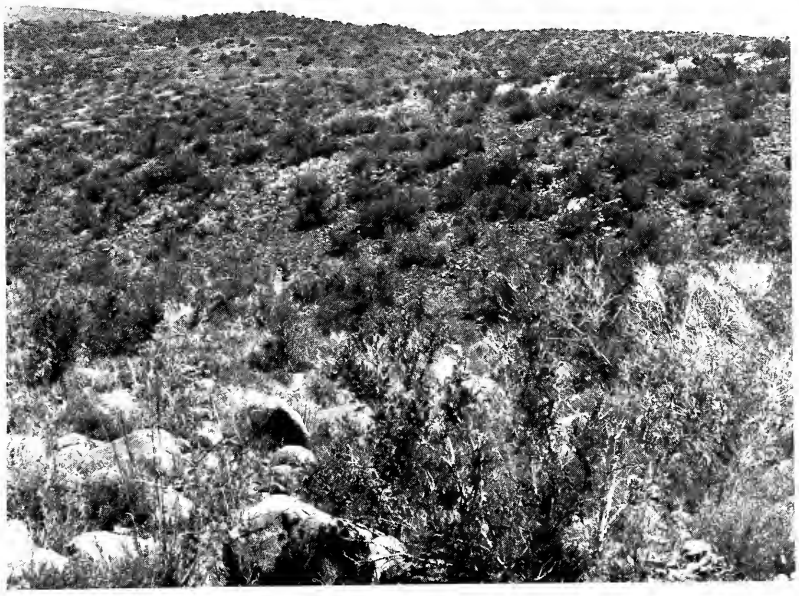


FIG. 45 - Stachyo - Rhoetum hermannietosum vestidae near Colesberg. In foreground *Diospyros austro-africana, Rhus erosa* and *Sporobolus fimbriatus*

FIG. 46 - Stachyo - Rhoetum hermannietosum vestidae between Colesberg and Petrusville. In foreground *Rhus undulata*. Note the narrow, deep valley of the Orange River and the absence of a gallery forest

high cover-abundance of *Salvia namaensis*, whereas the ground layer of 0,05 m high, usually covers less than 5 %.

On the northerly facing Beaufort sandstone slopes, steeper than 10 °, mainly in the area between Aliwal North and Bethulie, the Nanantho vittati-Rhoetum occurs (Figs 40 and 47). Rarely is the association encountered on southerly facing slopes, and in such cases the slopes are usually less than 10 °. The soils on which the association is found, are shallow lithosolic, sandy loams, with a pH between 5,5 and 7,0. The soils contain a large fraction of coarse gravel. The succulents *Nananthus vittatus* and *Haworthia tesselata,* the grasses *Brachiaria serrata* (d) and *Hyparrhenia hirta* (d) and the forbs *Dicoma macrocephala* (d) and *Asclepias fruticosa* (d) are character or positive differential species for the association. *Hyparrhenia hirta* is particularly abundant on sites where a gully has been initiated. Among the many other species occurring in the association the most important are *Rhus ciliata, R. undulata* var. *tricrenata, R. erosa, Euclea coriacea, Aristida diffusa* var. *burkei, Heteropogon contortus, Eragrostis curvula, Cymbopogon plurinodis* and several Pentzio-Chrysocomion species. It is further remarkable that *Tarchonanthus camphoratus* and *Euclea crispa* are virtually absent from the association (Table 11).

The Nanantho vittati-Rhoetum usually consists of three vegetation strata: a ground layer, a dwarf shrub and grass layer and a shrub layer. Rarely is a low tree layer of *Olea africana,* 5 to 6 m tall and covering less than 10%, present. The shrub layer is between 1 and 4 m high and covers 15 % on the average, although values of up to 25 % are occasionally reached. The dwarf shrub and grass layer is usually 0,70 m to 0,80 m high, and when *Hyparrhenia hirta* is present, up to 1,20 m high, covering 40 % on the average, but with a range of cover values from 15 to 70 %. The ground layer less than 0,05 m high, rarely covers more than 5 %. Total cover of the vegetation layers averages 50 %, but is occasionally as low as 15 %.

The communities preliminarily described by Werger (1973a) under the name *Rhus erosa-Rhynchelytrum repens* Group of Communities, from the vicinity of Bethulie are included in the Nanantho vittati-Rhoetum.

The Osteospermetum leptolobi, the Stachyo-Rhoetum and the Nanantho vittati-Rhoetum have a number of species in common, which are absent or nearly so from the other Rhoetea erosae communities. On the basis thereof these associations are combined into the alliance Hibisco marlothiani-Rhoion erosae. Character and differential species are the dwarf shrubs *Pegolettia retrofracta* (d), *Melolobium microphyllum, Helichrysum zeyheri, H. lucilioides* (d), *Eriocephalus pubescens* (d), *Thesium spartioides* and *Trichodiadema pomeridianum,* and the forbs *Hibiscus marlothianus, Aptosimum depressum, Chascanum pinnatifidum, Blepharis villosa* and *Anacampseros lanigera.* The species *Helichrysum lucilioides, Blepharis villosa* and *Anacampseros lanigera* have not been recorded in the Nanantho vittati-Rhoetum, whereas *Hibiscus*

FIG. 47 - Nanantho vittati - Rhoetum near Bethulie. Large shrubs are *Rhus erosa*

marlothianus, Aptosimum depressum, Thesium spartioides, Eriocephalus pubescens and *Trichodiadema pomeridianum* were seldom recorded in that association. On these grounds the distinction of a separate suballiance formed by the Osteospermetum leptolobi and the Stachyo-Rhoetum can be considered, but is regarded as superfluous here.

The Hibisco marlothiani-Rhoion erosae includes all communities on shallow soils on the slopes of Beaufort sandstones and mudstones and dolerite in the False Upper Karoo and some isolated localities further westwards, where conditions are not mesic.

In the entire area between Aliwal North and Petrusville, steep dolerite slopes, over 10°, with an aspect mainly between southeast and southwest, occur. The soil is shallow, loamy and rocky, and its pH between 5,5 and 6,5. These less xeric sites form the habitat of the Mayteno polyacanthae-Oleetum africanae. Character and differential species of this association are the low trees or shrubs *Maytenus polyacantha* and *Celtis africana* (d), the forbs *Asparagus laricinus* (d), *Pelargonium aridum, Senecio hieracioides* (d) and perhaps *Crassula setulosa,* and the fern *Mohria caffrorum* (d). *Stachys rugosa* var. *linearis* can also occur in this association, but is not as typical as in the Stachyo-Rhoetum or the Setario lindenbergianae-Buddlejetum salignae. Species that are also important in the association are, for example, *Rhus erosa, R. ciliata, Sutera halimifolia, Eragrostis curvula, Eustachys mutica, Diospyros lycioides* subsp. *lycioides, Tarchonanthus camphoratus* and several others (Table 11).

The association consists of two subassociations. On sheltered sites the typical form of the association occurs (Fig. 49). *Olea africana* and *Rhus undulata* var. *tricrenata* are very important in this community. On the less sheltered, more xeric sites the chamareetosum occurs, for which *Chamarea capensis* is the differential species. Typical for the chamareetosum are also the high cover-abundance values reached here by *Aristida diffusa* var. *burkei, Diospyros austro-africana* and *Lightfootia albens.* The distribution of the two subassociations in the study area is shown in Fig. 48.

Relevé 44 is not fully representative. It was situated in a steep gully where run-off from the slope concentrated after thunderstorms, washing away the shallow soil and the shallow-rooted plants.

The typical form of the Mayteno polyacanthae-Oleetum africanae consists of four vegetation layers: a small tree layer, 5 to 6 m in height with a range in cover from 15 to 80%; a shrub layer, 1 to 3 m high, covering between 25 and 60%; a dwarf shrub and grass layer, 0,60 to 0,70 m high, usually covering about 30% and an extremely sparse ground layer less than 0,05 m high. Total cover of this community averages 80 to 85%.

The chamareetosum consists of three vegetation layers: a shrub layer of 1 to 3 and sometimes 4 m high, usually covering approximately 30%, a dwarf shrub and grass layer, 0,60 to 0,70 m in height, generally covering between 50 and 55%, and a ground layer, 0,05 m in height, seldom covering more than 5%. Total cover of this subassociation amounts to about 65 to 70%.

The *Rhus erosa-Stachys burchelliana* Community and one of the *Olea africana - Maytenus heterophylla* Communities, both occurring in Tussen die Riviere Game Farm, O.F.S. (Werger, 1973a) are included in the Mayteno polyacanthae-Oleetum africanae.

On the isolated, doleritic inselbergs downstream from Petrusville, and also on dolerite

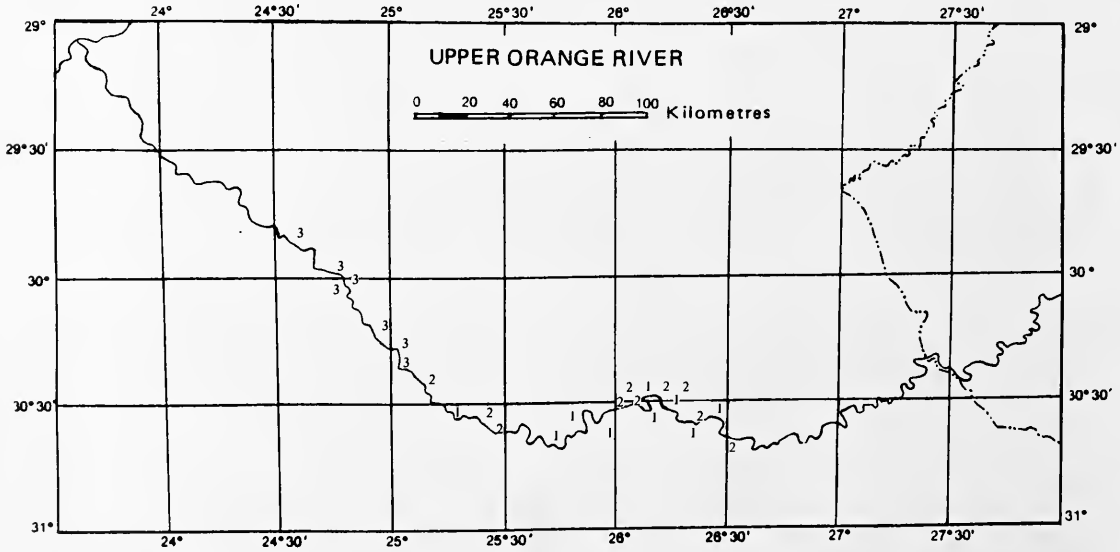


FIG. 48 - Distribution of Mayteno polyacanthae - Oleetum **africana typicum (1) and chamareetosum (2) and of Setario** lindenbergianae - Buddlejetum **salignae (3)** in the Upper Orange River area

slopes a few miles upstream from Petrusville, the Setario lindenbergiana-Buddlejetum salignae occurs (Figs 48 and 50). The typical habitat of this association is formed by the southerly or westerly facing steep slopes, over 20°, just below the summits of the mountains. The soils consist of shallow sandy loams with a pH between 6,0 and 7,0. Coarse gravel and large boulders are abundant in this habitat. Character and differential species of the association are the grass *Setaria lindenbergiana*, the shrubs *Buddleja saligna* and *Osyris lanceolata* (d), the forbs *Asparagus striatus* (d) and *Solanum retroflexum* and the pachycaulous (cf. Corner, 1954) or tuft tree *Cussonia paniculata* (d). Other species of occasional importance in the association are *Stachys rugosa* var. *linearis, Salvia namaensis, Themeda triandra, Rhus undulata* var. *tricrenata, Sporobolus fimbriatus, Euclea crispa, Digitaria eriantha,* and a few others (Table 11). The number of species recorded in the relevés of this association varies considerably, depending on whether the relevé was taken on a somewhat sheltered or on an exposed site.

The association is four or three-layered. Occasionally there is an open tree layer of *Cussonia paniculata*, up to 6 or 7 m tall, covering less than 10%. The shrub layer is up to 4,5 m high, covering between 10 and 25%. The dwarf shrub and grass layer is up to 1 m in height and often covers 50% or more. The ground layer less than 0,05 m high, is always very sparse. Total cover varies between 35 and 75%, depending on the quantity of large boulders present at each locality.

A number of species are common to the Hibisco marlothiani-Rhoion erosae, the Mayteno polyacanthae-Oleetum africanae and the Setario

FIG. 49 - Mayteno polyacanthae - Oleetum africanae typicum in Tussen die Riviere Game Farm, O.F.S., near Bethulie. Rounded trees are *Olea africana*

FIG. 50 - Orange River a few kilometres upstream from Petrusville. In foreground Setario lindenbergianae - Buddlejetum salignae; locally along the river Zizipho - Acacietum karroo and on opposite slope mainly Zizipho - Rhigozetum obovati

lindenbergianae-Buddlejetum salignae, which are absent from the Grewio-Rhoetalia erosae (Tables 10, 11) and so the first three are combined into the Rhoetalia ciliato-erosae, characterized by the following species: the dwarf shrubs and forbs *Limeum aethiopicum* (d), *Sutera albiflora, S. halimifolia, Rhus ciliata, Nenax microphylla* and *Lotononis laxa,* the shrub *Euclea coriacea* and the succulent *Aloe broomii.*

Thus, the order Rhoetalia ciliato-erosae largely comprises the shrub communities of the hillsides of the False Upper Karoo, whereas the order Grewio-Rhoetalia erosae comprises mainly the shrub communities of the hillsides of the more temperate grassland region east of the False Upper Karoo. Since the Rhoetalia ciliato-erosae are contact communities of the Hermannio coccocarpae-Nestleretum confertae, which occur on the deeper soils on the plains of the False Upper Karoo, the Rhoetalia ciliato-erosae are more heavily intruded by Pentzio-Chrysocomion species than the Grewio-Rhoetalia erosae. Apart from being contact communities this might be due to greater similarity in climatic conditions between the Hermannio coccocarpae-Nestleretum confertae and the Rhoetalia ciliato-erosae than between the former and the Grewio-Rhoetalia erosae.

The restriction of the shrub communities in these semi-wet to semi-arid areas to slopes with shallow, rocky soils is ascribed by Walter (1962) to the particular soil structure and soil moisture regime of these soils compared to the deep loamy soils of the plains. The conditions on the slopes favour deep- and extensively-rooting, woody vegetation, whereas on the plains plants with intensive shallow root-systems are favoured.

Some of the communities described by Potts & Tidmarsh (1937) in general terms, although not identical to certain communities described at present, are probably Rhoetalia ciliato-erosae communities. Particularly the communities which they name "Koppie Scrub" and *Rhus ciliata - Themeda triandra* Community show considerable floristic affinities to the Rhoetalia ciliato-erosae. Similar considerations seem to apply to some of Mostert's (1958) "Randjie Veld Communities" and to Müller's (1970) "Dry Grassland Sociations".

The Rhoetalia ciliato-erosae and the Grewio-Rhoetalia erosae share a large number of species and are combined into the class Rhoetea erosae. The following species typify this syntaxon: the trees and shrubs *Rhus erosa, R. undulata* var. *tricrenata, Diospyros austro-africana, D. lycioides* subsp. *lycioides, Olea africana, Tarchonanthus camphorathus* and *Euclea crispa;* the dwarf shrubs *Lightfootia albens, Selago albida, Hermannia cuneifolia* var. *glabrescens* and *Lantana rugosa;* the grasses *Aristida diffusa* var. *burkei, Heteropogon contortus, Themeda triandra, Eragrostis curvula, Eustachys mutica, Sporobolus fimbriatus, Cymbopogon plurinodis, Enneapogon scoparius, Digitaria eriantha* and *Rhynchelytrum repens;* the forbs *Hibiscus pusillus, Helichrysum dregeanum, Solanum supinum, Solanum coccineum, Dianthus basuticus* subsp. *basuticus, Argyrolobium lanceolatum* and *Anthospermum rigidum;* the leaf-succulents *Adromischus rupicola* and *Cotyledon decussata-orbiculata* complex and the ferns *Cheilanthes hirta, C. eckloniana* and *Pellaea calomelanos* (Tables 10, 11).

A number of these Rhoetea erosae character species do not occur as abundantly in the Grewio-Rhoetalia erosae as in the Rhoetalia ciliato-erosae. Others do not occur in all the Grewio-Rhoetalia erosae communities, but differentiate positively, as mentioned above, between the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum on the one hand and the Rhamno-Rhoetum on the other (Table 10).

With the exception of *Aristida diffusa* var. *burkei,* the Rhoetea erosae species are only infrequently present in the Osteospermetum leptolobi. This association is conspicuously open and occurs on gentle slopes. These gentle slopes, together with the plains of the False Upper Karoo, are considerably more overgrazed than the steeper slopes. This may account for the frequent absence of many species, particularly grasses. The general floristic composition of the Osteospermetum leptolobi, however, justifies the classification of this association in the Rhoetalia ciliato-erosae and consequently in the Rhoetea erosae.

In the class Rhoetea erosae all the shrub communities of the shallow soils occurring on hillsides in the False Upper Karoo and the *Cymbopogon-Themeda* Veld, and in which several species of *Rhus,* particularly *Rhus erosa* and *R. undulata* var. *tricrenata,* are dominant or conspicuous, are combined into a single syntaxon. The western boundary of the distribution area of the Rhoetea erosae coincides with the boundary between the Sudano-Zambesian and the Karoo-Namib floral Regions in the Upper Orange River area.

5.5 THE SHRUB AND DWARF SHRUB COMMUNITIES OF THE ROCKY SOILS OF THE WESTERN UPPER ORANGE RIVER VALLEY (PENTZIETEA INCANAE)

(Table 12)

5.5.1 Introduction

Downstream from Petrusville the scenery in the Upper Orange River area changes abruptly. Emerging from a narrow trough through a dissected countryside that commences near Colesberg, the Orange River reaches a flat monotonous landscape, just west of Petrusville, where the only relief consists of a few isolated inselbergs. The substrate is formed by Ecca and Dwyka deposits and, in the westernmost section of the Upper Orange River, by Ventersdorp lavas. Only the upper parts of the inselbergs consist of Beaufort deposits and dolerite (see Chapter 2.3). Thick calcrete layers occur over extensive stretches of land and pans are found throughout the area (cf. Chapters 2.4 & 2.5). Soils are usually lithosols or of a sandy loam type except in some localities north

of the river, and in lees south of the river where thick deposits of Kalahari sand have accumulated (cf. Chapter 2.5). The vegetation of this area is classified by Acocks (1953) mainly as False Arid Karoo and False Orange River Broken Veld. It is characterized by a large number of species typical of the Karoo-Namib floral Region and particularly by what are called by Acocks (1953) the "white desert grasses" or grasses of the genus *Stipagrostis*. This vegetation occurs infrequently in small xeric pockets in the area east of Petrusville upstream as far as Skurwekop, but west of Petrusville it is the main type. This vegetation extends westward considerably beyond the Upper Orange River area, changing gradually into the shrubby vegetation of Bushmanland and the dwarf shrub savanna (Giess, 1971) of South West Africa.

The following syntaxa will be discussed in this section (the relationships between the syntaxa are symbolized by the code in front of the syntaxa names):

II	Pentzietea incanae
IIA	Pentzio incanae-Rhigozetalia trichotomi
IIA1	Enneapogono scabri-Rhigozion obovati
IIA1a	Zizipho-Rhigozetum obovati
(1)	cheilanthetosum ecklonianae
(2)	inops
IIA1b	Melhanio rehmannii-Hermannietum spinosae
IIA2	Zygophyllion gilfillani
IIA2a	Monechmatetum incani
(1)	typicum
(2)	pentzietosum calcareae
IIA2b	Nestlero minutae-Pteronietum sordidae
(1)	typicum
(2)	stipagrostietosum ciliatae
IIB1a	Eriocephalo-Eberlanzietum

5.5.2 The communities

On the slopes of the deep and narrow valley trough and the surrounding mountains between Skurwekop and Petrusville and on several slopes of inselbergs in the area from Petrusville to Hopetown, the Zizipho-Rhigozetum obovati occurs (Figs 51, 52, 53 and 54). Its habitat nearly always consists of dolerite slopes, sometimes interrupted by layers of Beaufort or Ecca sandstones, mudstones or shales covered by a shallow lithosol, which contains a large amount of gravel, fine as well as coarse, and has a pH varying from slightly acid to slightly alkaline (5,5 to 8,0). The association is characterized by a number of differential species, several of which are Rhoetea erosae species which reach their westernmost limit here and occur together with species typical of more arid areas. These species are the small trees and shrubs *Ziziphus mucronata* (d), *Rhus undulata* var. *tricrenata* (d), *Acacia karroo* (d), *Olea africana* (d), *Diospyros austro-africana* (d), *Hermannia cuneifolia* var. *glabrescens* (d) and *Rhus ciliata* (d), the grasses *Digitaria eriantha* (d) and *Themeda triandra* (d), the forbs *Hibiscus pusillus* (d), *Pollichia campestris* (d), *Argyrolobium lanceolatum* (d), *Polygala asbestina* (d), *Asparagus striatus* (d), *Asclepias fruticosa* (d) and *Stachys rugosa* var. *linearis* (d) and possibly the aerial hemiparasite *Viscum rotundifolium* (d). *Ziziphus mucronata* and *Acacia karroo,* which occur as large trees in the riverine forests, occur only as rather small shrubs in the Zizipho - Rhigozetum obovati and thus show a reduced vitality in this association. Amongst the many other species occurring in the association, several grasses can be important, such as *Aristida diffusa* var. *burkei, Enneapogon scaber, E. scoparius, Heteropogon contortus, Fingerhuthia*

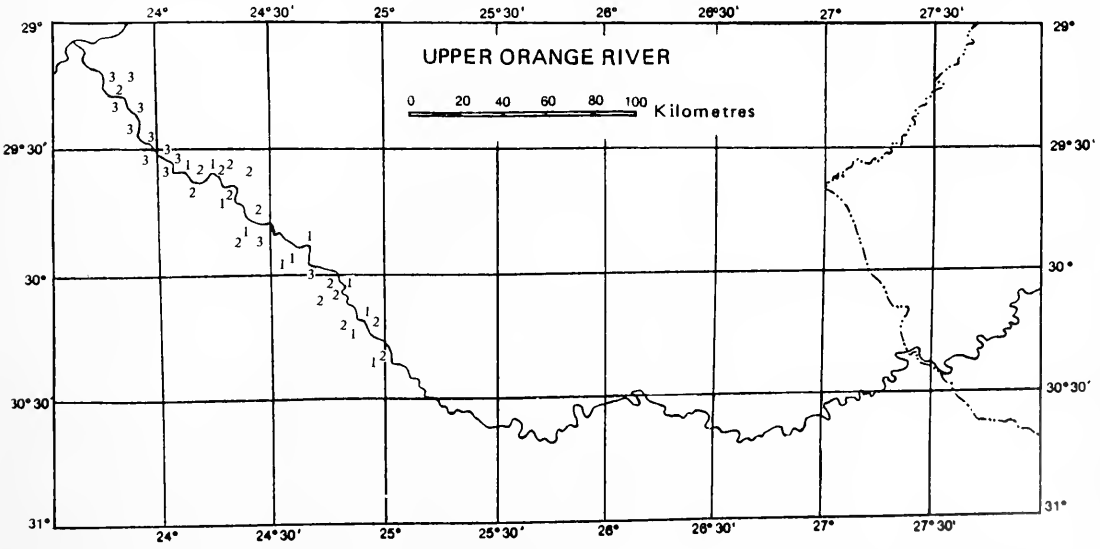


FIG. 51 - Distribution of Enneapogono scabri - Rhigozion obovati in the Upper Orange River area. 1. Zizipho - Rhigozetum obovati cheilanthetosum ecklonianae; 2. Zizipho - Rhigozetum obovati inops; 3. Melhanio rehmannii - Hermannietum spinosae

africana, Sporobolus fimbriatus, Aristida congesta, A. adscensionis and *Eragrostis lehmanniana*. Also the shrubby *Rhigozum obovatum, R. trichotomum* and *Boscia albitrunca*, and the dwarf shrub *Chrysocoma tenuifolia* can be of importance in this association (Table 12).

Two subassociations of the Zizipho-Rhigozetum obovati are distinguished. On steeper slopes, inclined at more than 15°, the subassociation cheilanthetosum ecklonianae is encountered, whereas on slopes with an inclination of up to 7° and rarely up to 15° the subassociation inops is found. The cheilanthetosum ecklonianae is usually found on middle and upper slopes, since here the inclination is usually greater than on the lower slopes (cf. Fair, 1948), where the subassociation inops more often occurs. There seems to be no clear correlation between slope direction (aspect) and the occurrence of these subassociations. The cheilanthetosum ecklonianae is

FIG. 52 - Zizipho - Rhigozetum obovati cheilanthetosum ecklonianae on dolerite in the vicinity of Orania. Large shrubs are *Rhigozum obovatum*. Also recognizable are *Aloe broomii, Rhus undulata, Ziziphus mucronata* and *Heteropogon contortus*. In the right background the wide, flat "Ecca landscape" is visible

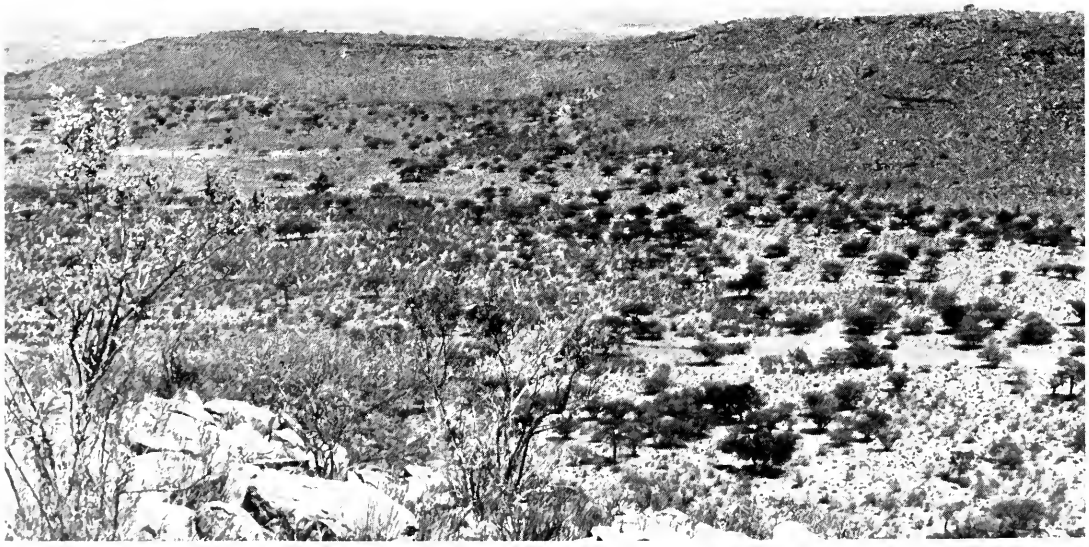


FIG. 53 - On the slopes in the foreground and middle background the Zizipho - Rhigozetum obovati occurs, while in the valley filled with Kalahari sand the Pentzio calcareae - Stipagrostietum acacietosum erioloba is found. In the distant background the wide and flat "Ecca landscape" between Hopetown and Douglas is visible (Photo F. v.d. Meulen)

FIG. 54 - Near Orania - Deep sandy flats carrying the Enneapogono desvauxii - Stipagrostietum, with *Stipagrostis ciliata* and *Rhigozum trichotomum*, are interrupted by dolerite outcrops covered with the Zizipho - Rhigozetum obovati. In foreground *Rhus undulata*

typified by the following differential species: the ferns *Cheilanthes eckloniana* and *Pellaea calomelanos*, the grasses *Cymbopogon plurinodis, Eustachys mutica* and *Rhynchelytrum repens*, the dwarf shrubs *Sutera albiflora* and *Melolobium microphyllum*, the forbs *Hibiscus marlothianus, Chascanum pinnatifidum, Sutera halimifolia, Solanum coccineum, Hermannia pulchra* and *Anthospermum rigidum*, the sedge *Mariscus capensis* and the leaf-succulent *Aloe broomii*. The shrub *Rhigozum obovatum* regularly reaches high cover-abundance values in this subassociation (Table 12).

The subassociation inops is generally not as rich in species as the cheilanthetosum ecklonianae. It seems to be typified by the infrequent occurrence of the shrub *Tarchonanthus camphoratus* and the dwarf shrub *Selago albida*, the former usually being abundant when it occurs (Table 12).

Relevé 520 is situated at Torquay, away from the main distribution area of the association in a sheltered ravine on a southeast-facing dolerite slope.

In both subassociations of the Zizipho-Rhigozetum obovati the vegetation usually consists of three strata. A small tree and shrub layer is from 1 to 3,5 and sometimes 4 m high and usually covers less than 10 %. A dwarf shrub and grass layer, up to 0,75 m in height, covers about 40 % and occasionally up to 75 %. The ground layer, less than 0,05 m high, is always sparse. Total cover averages 40 % but ranges from 20 to 80 %. Although some of the shrubs and small trees are evergreen, most are deciduous.

Downstream from Hopetown, as far as the confluence with the Vaal River, the Orange River has cut a moderately deep valley with convex sides through andesitic Ventersdorp lava (cf. Chapter 2.4). The slopes of the valley sides are seldom over 15 ° and bear a shallow, rocky lithosol of loamy sand with a large fraction of coarse gravel. The pH of this lithosol is usually between 5,5 and 6,5. The same soil is found on the lava plateau just outside the valley trough. On these shallow lava-derived lithosols, without correlation with slope direction, the Melhanio rehmannii-Hermannietum spinosae occurs (Figs 51, 55 and 56). It is a shrub community characterized by the following character and differential species: the small tree and shrub *Acacia tortilis* subsp. *heteracantha* (d) and *Grewia flava* (d), which find in the karroid area their optimum in this association but which are wide-spread further north (cf. Leistner & Werger, 1973), the grasses *Oropetium capense* (d) and *Eragrostis nindensis* (d), both of which possess extreme desiccation-tolerant mature foliage (Gaff, 1971 Gaff & Ellis, 1974), and the dwarf shrubs and forbs *Hermannia spinosa, Lasiocorys capensis* (d), *Melhania rehmannii, Blepharis mitrata, Barleria lichtensteiniana, Hermannia desertorum, Mestoklema tuberosum, Hoodia gordonii* (d) and *Aloe claviflora* (d), the latter three species being succulents. Amongst the most important other species occurring in this association are the grasses *Aristida diffusa* var. *burkei* and *Enneapogon scaber*, the shrubs *Rhigozum trichotomum, Acacia mellifera* subsp. *detinens, Rhigozum obovatum* and *Phaeoptilum spinosum* and several Pentzio-Chrysocomion species.

Relevés 348 and 371 are transitional between the Melhanio rehmannii-Hermannietum spinosae and the Zizipho-Rhigozetum obovati. They are situated on hot, steep dolerite slopes, inclined 19 ° and 14 ° respectively, upstream of the main distribution area of the Melhanio rehmannii-Hermannietum spinosae, towards the higher rainfall area.

The Melhanio rehmannii-Hermannietum spinosae is usually three-layered. A small tree and shrub layer, 1 to 3 m tall, exceptionally up to 4 m tall, covers generally between 3 and 30 %, although occasionally values of up to 50 % are reached. The

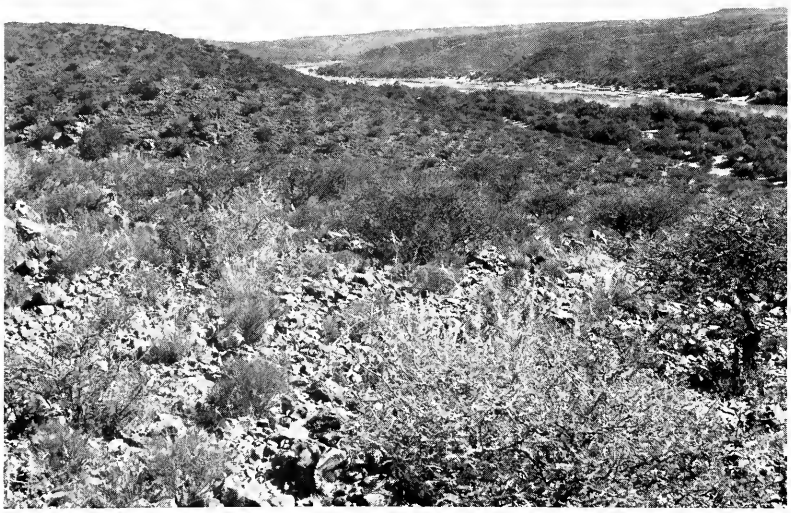


FIG. 55 - Melhanio rehmannii - Hermannietum spinosae, with much *Acacia mellifera* subsp. *detinens* and some *Rhigozum trichotomum*, near Hopetown. Note moderately steep valley sides of the Orange River cut through Ventersdorp lava

dwarf shrub and grass layer usually less than 0,50 m in height, covers 30 % on the average, with a range from about 10 to 40 %. The ground layer, less than 0,05 m high usually covers less than 5 %.

The Zizipho-Rhigozetum obovati and the Melhanio rehmannii-Hermannietum spinosae have a number of species in common, which do not occur in the other Pentzietea incanae communities. Based upon these floristic similarities the two associations are combined into the syntaxon Enneapogono scabri-Rhigozion obovati. The shrub *Rhigozum obovatum,* the grasses *Aristida diffusa* var. *burkei* (d), *Enneapogon scaber, E. scoparius* (d), *E. cenchroides* (d), *Sporobolus fimbriatus* (d) and *Heteropogon contortus* (d) and the dwarf shrubs and forbs *Phyllanthus maderaspatensis, Pegolettia retrofracta* (d), *Corbichonia decumbens, Lantana rugosa* (d), *Indigofera sessilifolia, Hermannia vestida, Solanum supinum* (d), *Senecio longiflorus* (d), *Helichrysum lucilioides* (d), *Abutilon austro-africana, Aptosimum depressum* (d) and *Sansevieria aethiopica* are character and positive differential species for the alliance. A number of these species are more common in and characteristic of the Rhoetea erosae communities but serve here as good positive differential species between this alliance and the other Pentzietea incanae communities (cf. Chapter 5.4). In the Enneapogono scabri-Rhigozion obovati the shrub and grass dominated communities of the False Arid Karoo and False Orange River Broken Veld in the Upper Orange River area **are united (Table 12).**

FIG. 56 - Close-up of Melhanio rehmannii - Hermannietum spinosae near Hopetown showing *Rhigozum trichotomum, Acacia mellifera* subsp. *detinens, Aristida congesta, et al.*

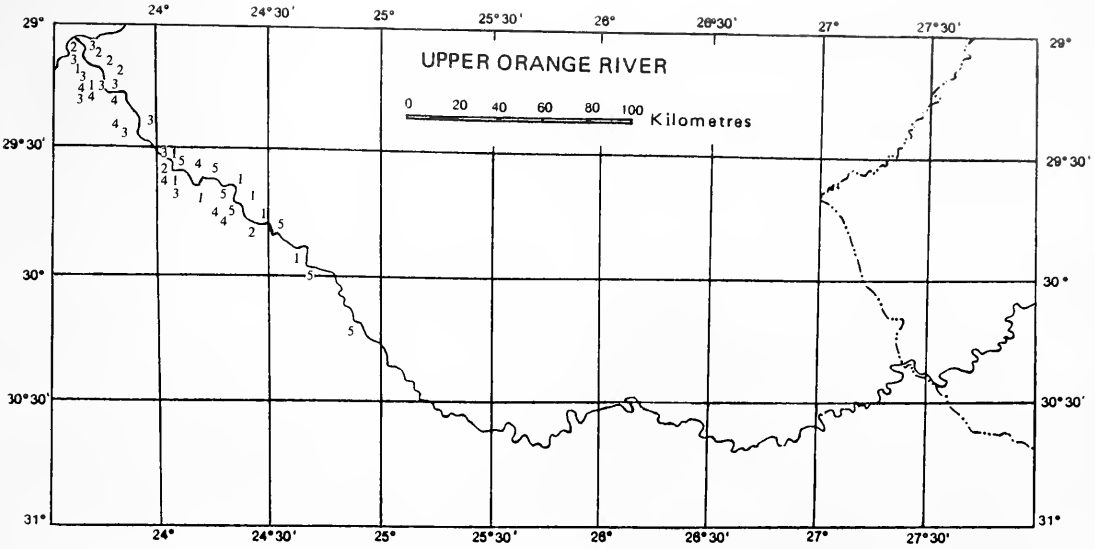


FIG. 57 - Distribution of Zygophyllion gilfillani and Ericephalo-Eberlanzietum in the Upper Orange River area. 1. Monechmatetum incani typicum; 2. Monechmatetum incani pentzietosum calcareae; 3. Nestlero minutae - Pteronietum sordidae pentzietosum calcareae; 4. Nestlero minutae - Pteronietum sordidae typicum; 5. Eriocephalo-Eberlanzietum

Downstream from Petrusville the Monechmatetum incani occurs (Fig. 57). The association is found on shallow, rocky, lithosols of loamy sand, often with a pH of 8,2, on the plateaux and gentle slopes, rarely sloping more than 5°, where some concentration of occasional sheet flow occurs such as in initiating gullies, or sometimes on the lower pediment slopes with inclinations of up to 10° or slightly more. It also occurs on sites, where the lava or calcrete plateau is overlain by a thin layer of Kalahari sand, usually less than 0,40 m thick, and where sheet flow is somewhat concentrated. Here the pH of the sandy topsoil is also generally between 8,0 and 8,2. The Monechmatetum incani has two character species, the dwarf shrubs *Monechma incanum* and *Pentzia spinescens*. Some Pentzio-Chrysocomion species and *Enneapogon desvauxii, Pentzia incana, Phaeoptilum spinosum, Aptosimum marlothii, Rhigozum trichotomum* and a few other species can also be important in the association (Table 12).

The subassociations of the Monechmatetum incani can be clearly distinguished. On the rocky loamy sand on the plateaux or pediplains and on the lower pediment slopes the subassociation typicum (Fig. 58) is found, while on the plateaux covered with Kalahari sand the subassociation pentzietosum calcareae (Fig. 59) occurs. Compared with the pentzietosum calcareae, the subassociation typicum is relatively rich in species. Species commonly occurring in the typicum and virtually absent from the pentzietosum calcareae are the shrubby *Acacia mellifera* subsp. *detinens, Boscia albitrunca* and *Ehretia rigida*, the grass *Fingerhuthia africana* and the dwarf shrubs and forbs *Limeum aethiopicum, Cyphocarpha angustifolia, Hermannia spinosa, Nestlera minuta* and *Plinthus karooicus*. Apart from the virtual absence of these species from the pentzietosum calcareae, this latter subassociation is characterized by the relatively high cover-abundance values reached here by *Pentzia calcarea* and perhaps by *Aptosimum marlothii* and *Eragrostis lehmanniana* (Table 12).

FIG. 58 - Monechmatetum incani typicum near drainage line in the vicinity of Douglas. *Monechma incanum* is clearly recognizable. In background *Acacia tortilis* and *Acacia mellifera* subsp. *detinens*

FIG. 59 - Monechmatetum incani pentzietosum calcareae between Hopetown and Douglas. In foreground *Phaeoptilum spinosum* and in background a "front" of *Rhigozum trichotomum*. Large termite heaps are visible, indicating that the sand is rather compact

A number of plants in this association, such as *Monechma incanum* (cf. Leistner & Werger, 1973) and *Pentzia calcarea*, are generally correlated with calcareous soils. The HCl-reaction on soil samples taken in the Monechmatetum incani only occasionally proved positive, but as Zólyomi (1963) explained, a more complete soils analysis is desirable since a high content of Ca-ions could then possibly have been correlated with the occurrence of lime-indicator species.

The Monechmatetum incani consists of either two or three vegetation layers. A shrub layer of usually *Acacia mellifera* subsp. *detinens, Rhigozum trichotomum, Phaeoptilum spinosum, Ehretia rigida* and small trees of *Boscia albitrunca*, often up to only 2 m in height, can be present and cover up to 40 %, although it usually covers only 5 % or less. A dwarf shrub and grass layer, 0,30 to 0,75 m high, is always present, generally covering between 20 and 30 %. A ground layer, less than 0,05 m high, is always very sparse.

Downstream from Orania the Ecca sandstones or Ventersdorp lava plateaux are frequently covered with a layer of sand which contains a fair amount of fine gravel and pebbles, often agates, jasper, chalcedony, and other minerals and rock. Calcareous concretions constitute an important component of these soils, and often the sand and gravel are completely cemented into a thick calcrete stratum. On these calcareous-rich soils on the flat to slightly sloping pediplains, which have a pH varying between 8,0 and 8,6 and always show a

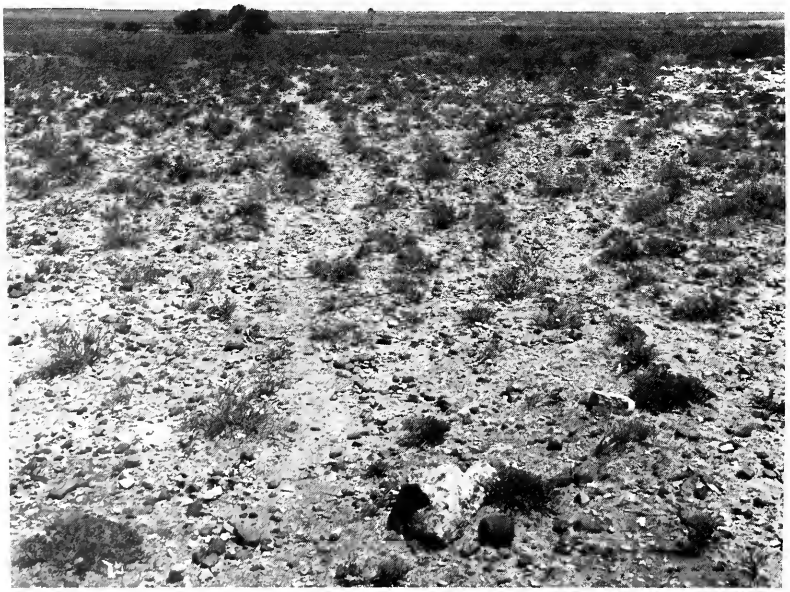
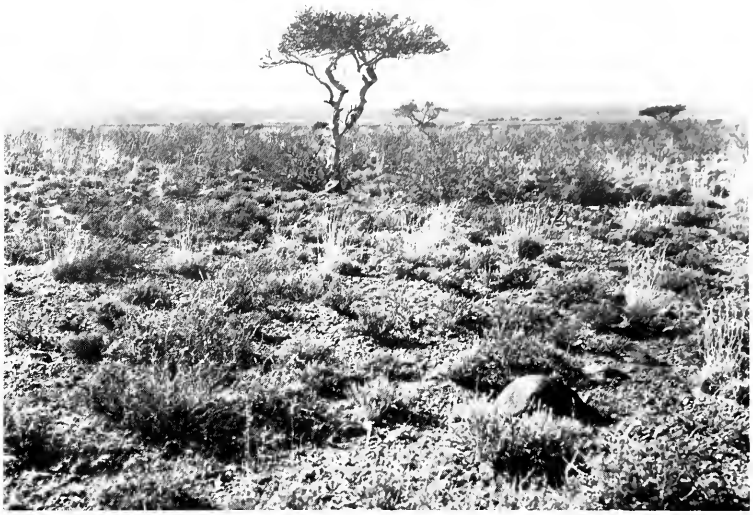


FIG. 60 - Typical view of Nestlero minutae - Pteronietum sordidae typicum on wide calcrete-covered plain near Kraankuil between Hopetown and Douglas. Compact dwarf shrubs are *Nestlera minuta*

FIG. 61 - Nestlero minutae - Pteronietum sordidae typicum south of the Orange River near the confluence with the Vaal River. *Boscia albitrunca* and a "front" of *Rhigozum trichotomum* are visible. The grass is *Stipagrostis ciliata*. In the distance a farm house



strong positive HCl-reaction, the Nestlero minutae-Pteronietum sordidae is found (Figs 57, 60, 61 and 62). It is typified by the following character and differential species: the dwarf shrubs *Nestlera minuta forma, Pteronia sordida, Hermannia pulverata, Aptosimum albomarginatum, A. spinescens* (d), *Lasiocorys capensis* (d), *Lycium pilifolium, Massonia microloma, Monechma desertorum* and possibly *M. distichotrichum*, the grass *Eragrostis truncata* and the succulent *Euphorbia aequoris*. Other species of importance in the association are *Enneapogon desvauxii, Zygophyllum gilfillani, Pentzia calcarea, Aptosimum marlothii, Chrysocoma tenuifolia* and a

FIG. 62 - Nestlero minutae - Pteronietum sordidae stipagrostietosum ciliatae near Torquay, with *Boscia albitrunca, Stipagrostis ciliata* and *Rhigozum trichotomum*

few others (Table 12).

Two subassociations of the Nestlero minutae-Pteronietum sordidae have been distinguished: the stipagrostietosum ciliatae and the typicum. The stipagrostietosum ciliatae occurs on the sand-covered plains derived from sandstone or lava, in which unconsolidated calcrete occurs as concretions and nodules. The soil is less than 1 m deep. This habitat is mostly found just below the minor break in the nearly horizontal lava plateau, forming a small scarp, where the Orange River incision starts. Just below these minor scarps there is a lee on which a thin layer of sand is deposited. The subassociation is typified by the occurrence of a considerable number of differential species of which the grass *Stipagrostis ciliata* and the woody plants *Rhigozum trichotomum, Acacia mellifera* subsp. *detinens* and *Boscia albitrunca* are the most important. Other differential species are *Lessertia pauciflora, Fagonia sinaica* var. *minutistipula, Fingerhuthia africana, Pteronia glauca, Polygala asbestina* and, to a lesser extent, *Acacia tortilis* subsp. *heteracantha* (Table 12).

The Nestlero minutae-Pteronietum sordidae typicum occurs on the flats, where the compactly cemented calcrete layer forms the surface. This subassociation virtually lacks the differential species mentioned above, but is characterized by the higher constancy and abundance with which *Pentzia calcarea* occurs and also by the somewhat higher constancy of the Pentzio-Chrysocomion species, *Eragrostis lehmanniana* and *Gnidia polycephala* (Table 12).

The stipagrostietosum ciliatae often consists of three vegetation strata. The uppermost layer of woody plants, such as *Acacia mellifera* subsp. *detinens, A. tortilis* subsp. *heteracantha, Rhigozum trichotomum, Phaeoptilum spinosum* and *Boscia albitrunca,* is usually less than 4 m in height and, if present, can cover up to 30%. The dwarf shrub and grass layer, 0,30 to 0,70 m high, generally covers about 30% whereas the ground layer, less than 0,05 m high, usually covers less than 5%.

The typicum is two-layered: A dwarf shrub and grass layer 0,20 to 0,45 m in height, covering between 15 and 35 %, is accompanied by a ground layer, less than 0,05 m high, covering between 5 and 45 %. The occasional high cover values of the ground layer are largely due to the high percentage of cover sometimes reached by *Eragrostis truncata* and *Enneapogon desvauxii.*

The Monechmatetum incani and the Nestlero minutae-Pteronietum sordidae are combined in the Zygophyllion gilfillani based on the following character and differential species: the dwarf shrubs *Zygophyllum gilfillani* and *Pentzia calcarea* (d) and the grass *Stipagrostis obtusa* (d) (Table 12). In this alliance the shrub and dwarf shrub dominated communities occurring in the Upper Orange River area of the False Arid Karoo and the False Orange River Broken Veld (Acocks, 1953) on calcium-rich substrates, are combined.

The shrubs *Rhigozum trichotomum, Acacia mellifera* subsp. *detinens* and *Ehretia rigida*, the low tree *Boscia albitrunca*, the dwarf shrubs and forbs *Cyphocarpha angustifolia, Pteronia glauca* and *Nestlera minuta* and the grasses *Fingerhuthia africana* and *Cenchrus ciliaris* are common to the Enneapogono scabri-Rhigozion obovati and the Zygophyllion gilfillani and absent from the following Pentzietea incanae community (Table 12). Therefore these alliances are combined into the Pentzio incanae-Rhigozetalia trichotomi and the species mentioned above are regarded as character species of this syntaxon.

Between Skurwekop and Hopetown, on level to slightly sloping plains of dolerite or Ecca sandstones overlain by a slightly acid to neutral loamy sandy soil, 0,25 m to approximately 1 m deep, containing a small fraction of fine gravel, the Eriocephalo-Eberlanzietum occurs (Fig. 57). It is an open community, characterized by the spiny, aizoaceous succulent *Eberlanzia spinosa,* the spiny dwarf shrubs *Eriocephalus spinescens* (d) and *Aptosimum spinescens* (d), the dwarf shrub *Hermannia comosa* (d) and by *Salsola glabrescens* (d), which occurs either as a shrub or a dwarf shrub. Very common in this association are also the shrub *Phaeoptilum spinosum* and the grass *Enneapogon desvauxii. Stipagrostis ciliata* and *S. obtusa* are occasionally abundant (Table 12).

Total cover values of the Eriocephalo-Eberlanzietum are usually rather low and generally range from 15 to 35%. Three vegetation strata are present: The open shrub layer, consisting mainly of *Phaeoptilum spinosum* is 1 to 2 m high and usually covers less than 5 %. The dwarf shrub and grass layer, up to 0,60 m high, covers between 10 and 25 %. The ground layer, less than 0,10 m in height, can be either sparse or can cover up to 20 %, depending mainly on the abundance of *Enneapogon desvauxii.*

The *Eberlanzia spinosa-Euphorbia mauritanica* Community described from the vicinity of Bloemfontein by Potts & Tidmarsh (1937), Mostert (1958) and Müller (1970) is syntaxonomically not related to the Eriocephalo-Eberlanzietum.

The Pentzio incanae-Rhigozetalia trichotomi and the Eriocephalo-Eberlanzietum are floristically related to one another and placed together in the class Pentzietea incanae. The shrub *Phaeoptilum spinosum,* the dwarf shrubs *Pentzia incana, Barleria rigida, Limeum aethiopicum, Aptosimum marlothii, A. leucorrhizum, Plinthus karooicus, Thesium hystrix, Eriocephalus pubescens* and *Polygala hottentotta* and the grass *Enneapogon desvauzii* characterize this class (Table 12). The Pentzietea incanae communities, apart from a number of Pentzio-Chrysocomion species and Rhoetea erosae species, regularly contain several accompanying species, of which *Aristida adscensionis, Dicoma macrocephala, Asparagus suaveolens, Tragus berteronianus, Eragrostis porosa* and *Geigeria filifolia* are the most common.

It is remarkable that the Enneapogono scabri-Rhigozion obovati, in particular the Zizipho-Rhigozetum obovati cheilanthetosum ecklonianae, contain so many Rhoetea erosae species, and the classification of this syntaxon in the Pentzietea incanae might seem debatable. Apart

from those Rhoetea erosae species occurring in the communities of the Enneapogono scabri-Rhigozion obovati, many others typical of that class are absent, such as *Rhus erosa, Eragrostis curvula, Lightfootia albens, Diospyros lycioides* subsp. *lycioides, Dianthus basuticus* subsp. *basuticus, Nenax microphylla, Helichrysum zeyheri* and several others. Other Rhoetea erosae species, although occurring in the Enneapogono scabri-Rhigozion obovati communities, consistently score considerably lower cover-abundance values here compared with the Rhoetea erosae. Such species are for example, *Rhus undulata* var. *tricrenata, Aristida diffusa* var. *burkei, Themeda triandra,* and others.

Furthermore, with Schwickerath's (1931) "Gruppenabundanzmethode" the strong floristic affinities of the Enneapogono scabri-Rhigozion obovati and of the Zizipho-Rhigozetum obovati with the other communities of the Pentzietea incanae, become apparent and this fully justifies the inclusion of the alliance in that class.

The Pentzietea incanae comprise the shrub and dwarf shrub communities on rocky, usually shallow soils of the semi-arid False Arid Karoo and False Orange River Broken Veld. It forms the natural continuation in the series from Grewio-Rhoetalia erosae (Chapter 5.4.2), through Rhoetalia ciliato-erosae (Chapter 5.4.3) to Pentzietea incanae which parallels the gradient from temperate mesic to hot semi-arid conditions. Whereas the Rhoetea erosae constitutes a class of Sudano-Zambesian communities, the Pentzietea incanae communities are Karoo-Namib.

From the southern Kalahari the Aizoo-Indigoferetum auricomae Leistner et Werger 1973 as well as the Sporobolo lampranthi-Zygophylletum tenuis Leistner et Werger 1973 were described. Although it is likely that these two associations belong to the Pentzietea incanae, information on the vegetation in the area interjacent to the southern Kalahari and the Upper Orange River is necessary to make a decision in this respect.

The Zygophyllo pubescentis-Stipagrostietum obtusae Volk et Leippert 1971, described from calcareous sites in the vicinity of Windhoek, South West Africa, was placed by the authors in the class Rhigozetea trichotomi Volk 1964 nom. nud., but it possibly belongs to the Pentzietea incanae, although not to the Pentzio incanae-Rhigozetalia trichotomi.

As it was not indicated which lower syntaxa were meant to be included in the class Rhigozetea trichotomi, in later publications by Volk (1966a) and Volk & Leippert (1971), it is left a nomen nudum.

Several dwarf shrubs of the Pentzietea incanae, particularly species of the genera *Pteronia, Plinthus, Salsola* and *Eriocephalus*, show a remarkable way of propagation by splitting their stems when they become older. This phenomenon was studied in detail by Theron (1964; Theron *et al.*, 1968) on *Plinthus karooicus*. It was found, that excentric secondary thickening followed by the formation of secondary periderm bridges running lengthwise through stem and root, ultimately cause the splitting of the main stem into a number of independent plants which are able to grow individually.

5.6 THE GRASSLAND COMMUNITIES ON KALAHARI SAND (STIPAGROSTION prov.)

(Table 13)

As far upstream as Colesberg, but mainly in the area downsteam from Petrusville, small to fairly large pockets of wind-blown Kalahari sand occur in lees and on the plains. These habitats characteristically bear a vegetation dominated by white *Stipagrostis* grasses. Because of severe overgrazing for just over a century the dominance of *Stipagrostis* species locally has given way to an abundant growth of *Rhigozum trichotomum* in particular. This species, but even stronger *Acacia mellifera* subsp. *detinens,* and to some extent *Acacia tortilis* subsp. *heteracantha*, have been involved in the bush encroachment in the communities on the hillsides with shallow soils, discussed in the previous Chapter 5.5 (Pentzietea incanae). According to the early travellers, these hillsides, and to a greater extent the plains covered with Kalahari sand, were grassier with a smaller woody component a century and a half ago than at present (see Chapter 2.6). As pointed out in Chapter 2.6, bush encroachment is a result of the disturbance of the equilibrium between woody vegetation and grass by overgrazing and trampling to the advantage of the woody vegetation, particularly as far as available soil moisture is concerned (cf. Walter, 1939, 1954b, c, 1962; Walter & Volk, 1954; Volk, 1966b; Giess, 1968). Because it mainly reproduces by forming suckers from rhizomes (Leistner, 1967; Giess, 1968; Leistner & Werger, 1973) (Figs 59 and 61), *Rhigozum trichotomum* usually occurs in these habitats in extensive colonies with a closed front.

In the Upper Orange River area two associations on Kalahari sand, both dominated by *Stipagrostis* species, have been distinguished (Table 13; Fig. 63).

Where dolerite or Ecca sandstones are overlain by a layer of slightly loamy Kalahari sand, possibly somewhat mixed with wind-blown alluvial sand, the Enneapogono desvauxii-Stipagrostietum occurs (Figs 64 and 65). Where this association is found, the sand layer is always deeper than 0,40 m and often deeper than 1 m deep. It usually contains a small fraction of fine gravel and occasionally some calcareous concretions as well. The soil is relatively compact compared with the majority of Kalahari sand deposits, and has a pH of 6,0 to 7,0 although when calcareous nodules are present, the pH might be as high as 8,4. These situations occur mainly in the area just downstream from Petrusville. Character and differential species of the association appear to be *Enneapogon desvauxii* (d) and

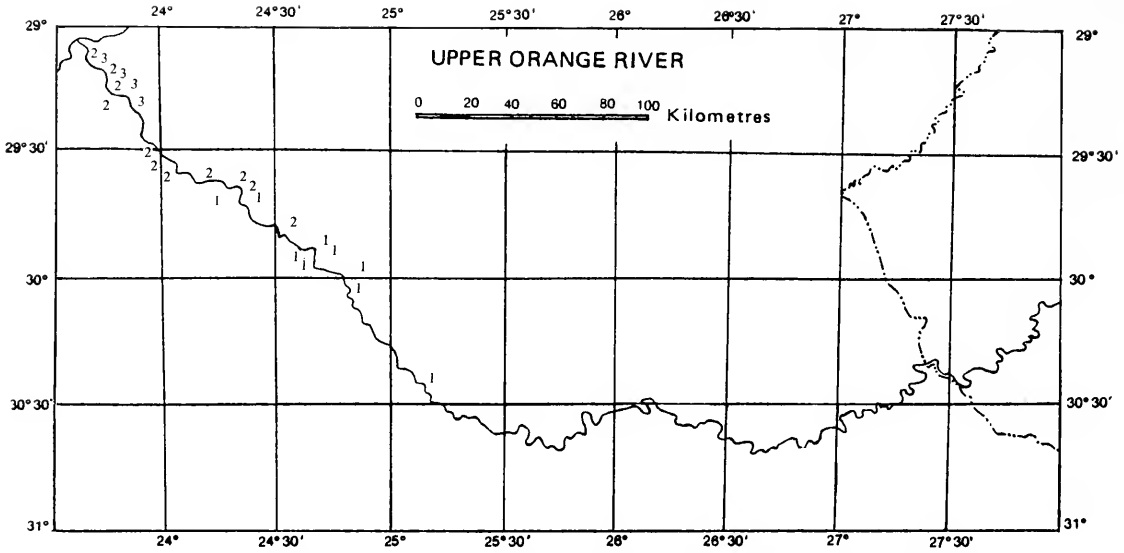


FIG. 63 - Distribution of Stipagrostion in the Upper Orange River area. 1. Enneapogono desvauxii - Stipagrostietum; 2. Pentzio calcareae - Stipagrostietum typicum; 3. Pentzio calcareae - Stipagrostietum acacietosum erioloba

FIG. 64 - Enneapogono desvauxii - Stipagrostietum in the vicinity of Orania, with *Stipagrostis ciliata, Stipagrostis obtusa* and *Rhigozum trichotomum*

FIG. 65 - Overgrazed plains of Kalahari sand near Kraankuil, carrying Enneapogono desvauxii - Stipagrostietum dominated by *Rhigozum trichotomum*

probably *Nestlera laxa,* while *Stipagrostis obtusa* and *S. ciliata* are abundant and *Plinthus cryptocarpus* is relatively frequent. Dense stands (facies) of *Rhigozum trichotomum* occur occasionally. Other species that are often found in this association are the pioneer grasses *Tragus berteronianus, Eragrostis porosa, E. lehmanniana* and *Aristida congesta* and the dwarf shrub *Chrysocoma tenuifolia* (Table 13).

The Enneapogono desvauxii-Stipagrostietum consists of two or three vegetation layers: A shrub layer of *Rhigozum trichotomum,* sometimes with *Phaeoptilum spinosum,* up to 1,50 m high can cover up to about 25 % and sometimes even more. The dwarf shrub and grass layer, 0,50 or 0,70 m in height, ranges in cover from as low as 5 % to as high as 50 %. The ground layer of less than 0,10 m high, can cover up to 15 %.

In the area downstream from Hopetown there are several localities, where the Kalahari sand deposit measures 1 m or more in thickness. Usually the underlying substratum consists of a thick, compactly cemented, calcareous layer and sometimes small calcareous nodules are found in the sand layer which does not contain a loamy fraction as is the case where the Enneapogono desvauxii-Stipagrostietum occurs. The pH of the sand varies from 7,0 to 8,4. The soil regularly gives a positive HCl-reaction, but even if it does not, a large amount of Ca-ions might still be expected in the soil, as pointed out in Chapter 5.5 and by Zólyomi, 1963. On these sands the Pentzio calcareae-Stipagrostietum is encountered. This association is characterized by the shrub or small tree *Acacia tortilis* subsp. *heteracantha* (d), the dwarf shrubs *Pentzia calcarea* (d), which is often abundant, *Aptosimum marlothii* (d), *Eriocephalus pubescens* (d) and *Hermannia comosa* (d) and the herbaceous plant *Nolletia arenosa.* The grasses *Stipagrostis obtusa* and *S. ciliata* are again constant and often abundant. *Rhigozum trichotomum* frequently occurs in the typical dense colonies. Other commonly encountered species in this association include *Tragus berteronianus, Phaeoptilum spinosum, Dicoma macrocephala, Chrysocoma tenuifolia, Aristida congesta* and *Eragrostis lehmanniana.* This description is characteristic for the typical form of the Pentzio calcareae-Stipagrostietum. Near Douglas, however, on sites where the Kalahari sand is at least 2 m deep, the subassociation acacietosum erioloba occurs (Figs 63, 66 and 67), typified by the occurrence of the large evergreen tree *Acacia erioloba* and perhaps the occurrence of *Polygala leptophylla* and the shrub *Lycium salinicolum* under the trees. This vegetation is part of the Kalahari Thornveld invaded by Karoo, Veld Type 17 (Acocks, 1953).

The Pentzio calcareae-Stipagrostietum in its typical form consists of two or three vegetation layers, depending on whether a shrub layer formed by *Rhigozum trichotomum, Phaeoptilum spinosum* and/or *Acacia tortilis* subsp. *heteracantha* is present or not. If present, the shrub layer is generally less than 2 m in height and covers up to 50 %. The dwarf shrub and grass layer is up to 0,60 m high, covering usually between 20 and 50 %. A ground layer, less than 0,05 m high, is always extremely sparse.

The Pentzio calcareae-Stipagrostietum acacietosum erioloba consists of four vegetation strata: an open tree layer up to 8 m tall, covering 5 % or less; an open shrub layer, up to 2 m in height, also covering less than 5 %; a dwarf shrub and grass layer up to 0,80 m high covering between 20 and 40 %, and a very sparse ground layer less than 0,05 m in height.

The inclusion of this subassociation into the Pentzio calcareae-Stipagrostietum is a clear example of the combination of structurally different syntaxa into one higher syntaxon on the basis of floristic criteria, as also applied by Van Donselaar (1965) in the savannas of Surinam, and discussed

FIG. 66 - Pentzio calcareae - Stipagrostietum typicum between Torquay and Douglas, showing *Acacia tortilis, Acacia mellifera* subsp. *detinens, Stipagrostis obtusa* and *Stipagrostis ciliata*

FIG. 67 - Rather badly grazed Pentzio calcareae - Stipagrostietum acacietosum erioloba near Douglas. Wind erosion has bared the roots of *Acacia erioloba* in centre. *Acacia tortilis* and *Stipagrostis ciliata* are also recognizable

by Werger (1974b).

The Kalahari sand accumulation forms the largest uninterrupted surface of sand in the world (Wellington, 1955) and in the southern part communities dominated by species of *Stipagrostis* are widespread. From the area delineated by Leistner (1967) as the southern Kalahari, a number of such communities are described (Leistner & Werger, 1973), such as the Peliostomo-Stipagrostietum obtusae Leistner et Werger *1973*, two *Monechma incanum-Stipagrostis ciliata* Communities, the Hirpicio-Asthenatheretum, Leistner et Werger 1973, and the Stipagrostietum amabilis, Leistner et Werger 1973.

The Peliostomo-Stipagrostietum obtusae, the two *Monechma incanum-Stipagrostis ciliata* Communities, the Enneapogono desvauxii-Stipagrostietum and the Pentzia calcareae-Stipagrostietum have the species *Stipagrostis obtusa, S. ciliata* and *Plinthus cryptocarpus* in common, and can therefore be combined into the alliance Stipagrostion prov., with the above three species as character species. When more data become available from the area lying between the Upper Orange River and the southern Kalahari, it is possible that more associations will have to be included in the Stipagrostion.

Although floristically related to the Stipagrostion, the Stipagrostietum amabilis and the Hirpicio echini-Asthenatheretum cannot be included in that alliance.

It is likely that, when enough data become available, the open grassy communities occurring on Kalahari sands in the arid and semi-arid areas of South West Africa, Botswana and South Africa, including Bushmanland, may be combined into a single syntaxon.

5.7 MINOR COMMUNITIES

Apart from the communities described in Chapters 5.2-6, a number of other communities occur in the Upper Orange River area, which are generally of limited spatial extent. Some of them, like those along roads and railway lines, and those occurring on the remnants of collapsed termitaria, have not been sampled, although some general observations have been made.

In the area upstream from Aliwal North, the roadside and railside communities often represent facies or fragments of the grassland communities described in Chapter 5.2. Some species like *Themeda triandra* and *Eragrostis curvula* are often abundant, and the phytocoenoses contain a considerable number of apophytes and neophytes. Total cover values are often relatively high in these communities since the roadside communities are hardly grazed at all and also more water is available to them owing to run-off from the asphalt.

Between Aliwal North and Petrusville the roadside and railside communities are similar to the Hermannio coccocarpae-Nestleretum confertae eragrostietosum curvulae and to the various Rhoetalia ciliato-erosae communities described in Chapters 5.3 and 5.4, although grasses are often more abundant. Apophytes and neophytes, like *Chloris virgata, Argemone subfusiformis* and *Salsola kali*, are locally abundant.

Downstream from Petrusville roadside and railside communities usually represent facies and fragments of Pentzietea incanae and Stipagrostion communities, described in Chapters 5.5 and 5.6. Locally again species like *Chloris virgata, Argemone subfusiformis, Salsola kali, Aristida adscensionis* and also *Psilocaulon absimile* can be abundant.

Termitaria are frequent, particularly on the plains covered with deep sandy loams on which the Hermannio coccocarpae-Nestleretum confertae occurs. Those that are inhabited are bare, but around their fringes and on the remnants of collapsed ones, *Sporobolus fimbriatus* and *Cynodon hirsutus* can be rather abundant, while *Asparagus suaveolens* is also encountered quite regularly on these habitats.

The plains with deep sandy loam soils, between Aliwal North and Petrusville, have occasional shallow depressions and damp sites where run-off concentrates and where the topsoil is slightly acid. Here a closed community with mat-forming grasses and dwarf shrubs is found. Relevé 276 represents this community, that might be called the *Cynodon-Pentzia* Community. The dwarf shrub layer of the *Cynodon-Pentzia* Community is 0,20 m high and covers approximately 5 %, whereas the grass layer is about 0,10 m high and covers 80 % (Table 14).

TABLE 14 - *Cynodon-Pentzia* Community

Relevé No.	276
SL	30 ° 37'
EL	25 ° 25'
Total cover (%)	80
Total No. of species	10
Pentzia globosa	1.2
Lycium salinicolum	+.2
Salsola glabrescens	+.2
Cynodon incompletus	4.4
Panicum stapfianum	1.3
Urochloa panicoides	1.2
Eragrostis curvula	1.2
Eragrostis obtusa	1.2
Mariscus capensis	+.2
Atriplex semibaccata	+.3

Also between Aliwal North and Petrusville in wide pan-like depressions or on eroding fans with a brackish, deep compact surface soil of sandy loam or loamy sand, with a pH between 7,5 and 8,2 the *Pentzia-Eragrostis truncata* Community occurs (Table 15).

TABLE 15 - *Pentzia - Eragrostis truncata* Community

Relevé No.	161	23	285	558	Sociability
SL (degrees)	30 ° 35'	30 ° 32'	30 ° 35'	29 ° 50'	
EL (degrees)	26 ° 27'	25 ° 53'	25 ° 16'	24 ° 34'	
Total cover (%)	25	65	10	65	
Total No. of species	6	15	17	5	
Pentzia globosa	+	2b	2a	4	1-2
Salsola glabrescens	2b	+	1	+	2
Chrysocoma tenuifolia	1	2b	r		1-2
Lycium salinicolum	1	1	+		2
Asparagus suaveolens		+	+	1	2
Hertia pallens			+	+	2
Nestlera conferta		+	+		2
Eragrostis truncata		3	+	+	3
Eragrostis lehmanniana	+	+	+		2
Tragus koelerioides	+	+	+		2
Eragrostis obtusa		+	+		2

Also occurring: Relevé 23- *Berkheya pinnatifida* (+), *Trichodiadema pomeridianum* (1), *Aptosimum depressum* (r), *Hermannia pulverata* (r), *Indigofera alternans* (+); Relevé 285- *Eriocephalus spinescens* (+), *Euphorbia mauritanica* (+), *Aristida congesta* (+), *Gazania krebsiana* (+), *Schizoglossum linifolium* (+), *Talinum caffrum* (+)

The community consists of two vegetation layers: a dwarf shrub and taller grass layer, up to 0,40 m in height, covering between 10 and 50 %, and a layer of mat-forming grasses and very low plants, 0,05 m high, covering up to 30 %.

TABLE 16 - *Pentzia-Zygophyllum incrustatum* Community

Relevé No.	72	13	397	557	Sociability
SL (degrees)	30 ° 40'	30 ° 38'	29 ° 48'	29 ° 48'	
EL (degrees)	25 ° 46'	25 ° 41'	24 ° 33'	24 ° 32'	
Total cover (%)	50	20	5	60	
Total No. of species	15	11	5	9	
Zygophyllum incrustatum	1	1	1	1	2
Salsola glabrescens	r	1	1	+	2
Pentzia globosa	2b	2a		3	1-2
Asparagus suaveolens	1		+	1	2
Drosanthemum sp.			+	+	1
Chrysocoma tenuifolia	r	1			1-2
Gazania krebsiana	+	+			2
Lycium salinicolum	+	+			2

Also occurring: Relevé 72- *Eragrostis truncata* (2a), *E. lehmanniana* (+), *Sporobolus fimbriatus* (+), *Aptosimum depressum* (+), *Felicia muricata* (+), *Talinum caffrum* (+), *Hermannia resedaefolia* (+), *Berkheya pinnatifida* (r); Relevé 13-*Limeum aethiopicum* (+), *Plinthus karooicus* (+), *Cynodon hirsutus* (+), *Tragus koelerioides* (+), *Eriocephalus spinescens* (r); Relevé 397- *Sporobolus pyramidalis* (+); Relevé 557- *Delosperma ornatulum* (+), *Chloris virgata* (3), *Aristida adscensionis* (+), *Enneapogon desvauxii* (+)

FIG. 68 - *Eragrostis truncata* - *Titanopsis schwantesii* Community in a calcrete pan near Petrusville. Wind erosion has caused the microrelief by blowing away the dust from the open spaces between the mats of *Eragrostis truncata*

TABLE 17 - *Lycium prunus-spinosa* Community

Relevé No.	353	398	365	367	369	370	413	Sociability
SL	30 ° 30'	29 ° 49'	29 ° 51'	29 ° 49'	29 ° 49'	29 ° 49'	29 ° 45'	
EL	24 ° 39'	24 ° 32'	24 ° 30'	24 ° 28'	24 ° 27'	24 ° 27'	24 ° 22'	
Total cover (%)	20	7	20	10	30	15	30	
Total No. of species	22	13	21	16	29	11	8	
Lycium prunus-spinosa	1	1	+	1	+	2a	2a	2
Salsola glabrescens	1	1	2a	2a	+	2a	2a	2
Zygophyllum incrustatum		+	+			1		2
Drosanthemum sp.	+	+	1					1-2
Blackiella inflata	+	+						1-2
Felicia burkei	+			1				2
Psilocaulon absimile		1	+					2
Pentzietea incanae species								
Enneapogon desvauxii	+	+	+	+	+	+		2
Pentzia incana	2a		+			+		1-2
Barleria rigida	+			+	+			1-2
Pentzia spinescens			+	1	1			1-2
Fingerhuthia africana				+	+			2
Thesium hystrix				+	+			2
Hermannia spinosa	+			+				2
Phaeoptilum spinosum			+		1			2
Pentzia-Chrysocomion species								
Lycium salinicolum	+	+	2a	+	+		2a	2
Aristida congesta	+		+		+			1-2
Chrysocoma tenuifolia	r		+		1			1-2
Pentzia globosa		+					1	1-2
Eragrostis lehmanniana			+				+	2
Other companion species								
Asparagus suaveolens	r	+	+	+	1	+		2
Tragus berteronianus	+	+	+	+		+	1	2
Aristida adscensionis	+	r	+		+	1		1-2
Asparagus laricinus				+	+	+		2
Stipagrostis obtusa				+	+			2
Sarcocaulon patersonii				+	+			1-2
Pteronia mucronata					+	+		2
Talinum caffrum	+		+					1-2
Chloris virgata			+				+	1-2

Also occurring: Relevé 353- *Rhigozum trichotomum* (2b), *Pteronia sordida* (+), *Zygophyllum gilfillani* (+), *Eragrostis porosa* (+), *Nycteranthus noctiflorus* (+), *Drosanthemum floribundum* (+); Relevé 398- *Aptosimum spinescens* (+); Relevé 365- *Eberlanzia spinosa* (+), *Osteospermum spinescens* (+), *Aloe claviflora* (+); Relevé 367- *Osteospermum spinescens* (+), *Pteronia acuminata* (+); Relevé 369- *Acacia mellifera* subsp. *detinens* (+), *Aptosimum marlothii* (1), *Limeum aethiopicum* (+), *Polygala leptophylla* (+), *Monechma incanum* (1), *Blepharis capensis* (+), *Selago albida* (+), *Tragus koelerioides* (+), *Caralluma lutea* (+), *Indigofera alternans* (+), *Stipagrostis ciliata* (+); Relevé 370- *Pteronia punctata* (+); Relevé 413- *Eragrostis bicolor* (1)

Between Bethulie and the vicinity of Petrusville in wide, nearly level, washes, where a slightly concentrated run-off occasionally occurs, and the loamy soil with a pH of between 7,0 and 8,0 contains a calcareous fraction, the *Pentzia-Zygophyllum incrustatum* Community occurs (Table 16). The community is two-layered. There is a dwarf shrub and grass layer of 0,15 to 0,45 m tall, covering 5 to 35 %, and a ground layer, less than 0,05 m high, covering up to 15 %.

It is uncertain whether the *Cynodon-Pentzia* Community, the *Pentzia-Eragrostis truncata* Community and the *Pentzia-Zygophyllum incrustatum* Community are floristically sufficiently related to the Hermannio coccocarpae-Nestleretum confertae that they can be combined into one syntaxon.

Between Petrusville and Hopetown on the plains formed by Ecca sandstones and shales, wide drainage lines or wide, shallow, dry stream-beds occasionally occur. The soil is a loamy sand, with a considerable amount of fine gravel and sometimes a few calcareous nodules. The pH is usually between 8,2 and 8,6 and the soil gives a strong positive HCl-reaction. In this habitat the *Lycium prunus-spinosa* Community occurs (Table 17). It is an open community with three vegetation layers. The shrub layer is usually not more than 1,50 m high and covers less than 10 %. The dwarf shrub and grass layer, 0,30 to 0,75 m high, usually covers

TABLE 18 - *Eragrostis truncata-Titanopsis schwantesii* Community

Relevé No.	387
SL	29 ° 53'
EL	24 ° 40'
Total cover (%)	65
Total No. of species	12
Eragrostis truncata	4.3
Titanopsis schwantesii	1.2
Polygala pungens	+.2
Hermannia pulverata	+.2
Thesium hystrix	+.2
Pentzia calcarea	+.2
Gnidia polycephala	r
Plinthus karooicus	+.2
Asparagus suaveolens	+.2
Enneapogon desvauxii	r
Lycium salinicolum	+.2
Nolletia ciliaris	+.1

between 5 and 20 %, and the ground layer, less than 0,05 m in height, is always extremely sparse. It is unlikely that the *Lycium prunus-spinosa* Community belongs to the Pentzietea incanae.

As pointed out in Chapter 2.4, several pans occur in the area downstream from Petrusville. These pans, when not bare, carry a vegetation which is often considerably different from the surrounding vegetation. From the southern Kalahari Leistner & Werger (1973) described several associations occurring on pan floors. These associations have, however, not been found in the Upper Orange River area. In the vicinity of Petrusville the vegetation of a calcrete pan was sampled (Table 18; Fig. 68). It consists of what might be called the *Eragrostis truncata-Titanopsis schwantesii* Community, which possibly belongs to the Pentzietea incanae. It is a unistratal vegetation of very low dwarf shrubs, succulents and grasses, up to 0,08 m high, covering approximately 65 %.

5.8 TYPIFICATION OF THE SYNTAXA

The Code of Phytosociological Nomenclature by J.J. Barkman, J. Moravec & S. Rauschert (1976, Vegetatio 32: 131-185) requires the identification of type relevés for newly described associations and subassociations, and of type syntaxa of lower rank for newly described syntaxa of higher rank.

The syntaxa described in this volume are typified as follows:

Associations and subassociations	**Type relevé**
Rhoo-Diospyretum	315
Rhoo-Diospyretum celtidetosum	252
Rhoo-Diospyretum acacietosum karroo	315
Zizipho-Acacietum karroo	418
Hermannio coccocarpae - Nestleretum confertae	73
Hermannio cocc. - Nestleretum conf. aptosimetosum marlothii	287
Hermannio cocc. - Nestleretum conf. eragrostietosum curvulae	73
Hermannio cocc. - Nestleretum conf. oropetietosum	146
Rhamno - Rhoetum	230
Rhoo - Aloetum ferocis	264
Blepharido - Rhoetum	209
Osteospermetum leptolobi	28
Osteospermetum leptolobi typicum	28
Osteospermetum leptolobi aptosimetosum marlothii	320
Stachyo - Rhoetum	129
Stachyo - Rhoetum polygaletosum	61
Stachyo - Rhoetum hermannietosum vestidae	129
Nanantho vittati - Rhoetum	151
Mayteno polyacanthae - Oleetum africanae	115
Mayteno polyac. - Oleetum afr. chamareetosum	107
Mayteno polyac. - Oleetum afr. typicum	115
Setario lindenbergianae - Buddlejetum salignae	335
Zizipho - Rhigozetum obovati	407
Zizipho - Rhigozetum ob. cheilanthetosum ecklonianae	407
Zizipho - Rhigozetum ob. inops	345
Melhanio rehmannii - Hermannietum spinosae	469
Monechmatetum incani	443
Monechmatetum incani typicum	443
Monechmatetum incani pentzietosum calcareae	503
Nestlero minutae - Pteronietum sordidae	471
Nestlero min. - Pteronietum sord. stipagrostietosum ciliatae	488
Nestlero min. - Pteronietum sord. typicum	471
Eriocephalo - Eberlanzietum	416
Enneapogono desvauxii - Stipagrostietum	363
Pentzio calcareae - Stipagrostietum	442
Pentzio calc. - Stipagrostietum typicum	442
Pentzio calc. - Stipagrostietum acacietosum erioloba	527
Lycium prunus-spinosa Community	398

Syntaxon	Type syntaxon
Diospyrion lycioidis	Zizipho-Acacietum karroo
Pentzio-Chrysocomion	Hermannio coccocarpae - Nestlerum confertae eragrostietum curvulae
Indigofero spinescentis - Rhoion erosae	Rhoo - Aloetum ferocis
Hibisco marlothiani - Rhoion erosae	Stachyo - Rhoetum hermannietosum vestidae
Rhoetalia ciliato-erosae	Hibisco marlothiani - Rhoion erosae
Rhoetea erosae	Rhoetalia ciliato-erosae
Enneapogono scabri - Rhigozion obovati	Melhanio rehmannii - Hermannietum spinosae
Zygophyllion gilfillani	Nestlero minutae - Pteronietum sordidae
Pentzio incanae - Rhigozetalia trichotomi	Enneapogo scabri - Rhigozion obovati
Pentzietea incanae	Pentzio incanae - Rhigozetalia trichotomi
Stipagrostion	Peliostomo-Stipagrostietum obtusae

Ecological outline and concluding remarks

It is apparent from the physiographic description in Chapter 2 that the overriding feature in the Upper Orange River area is the more or less east-west gradient following the course of the river. This gradient is a result of parallel changes; in altitude, from nearly 1 400 m in the east to just below 1 000 m in the west of the study area; in climate, from warm temperate and relatively humid near Lesotho to a hot and dry steppe or semi-desert climate near Douglas; in geology, from the Upper Karoo strata emerging near Sterkspruit to the Lowest Karoo strata and ancient Ventersdorp lava emerging in the section between Hopetown and the Orange-Vaal confluence; in geomorphology, from the strongly dissected country upstream from Aliwal North to the monotonous flat landscape downstream from Petrusville; and in soils, from the Highveld prairie soils on the eastern plateau to the aeolian Kalahari sands in the westernmost part of the Upper Orange River area. Such a change in all physiographic factors necessarily implies a change in general ecology along the gradient which can be expected to find its expression in the communities in the area. The changes in general ecology or habitat features can be expressed in a community both in the constituent species and their autecology as well as in community structure.

In studying the expression of changing habitats of the various communities in the species composition and structure of the communities in the Upper Orange River area, a second factor should be taken into account. This is the situation in the landscape, as a result of which the moisture regime of the soil is basically different (cf. Batanouny & Sheikh, 1972). As a result of different situations in the landscape three major types of habitat can be distinguished:

1. The deep sandy levees along the river, which probably store a large amount of water and carry a riverine forest and woodland vegetation.
2. The slopes which have shallow, well-drained, rocky lithosols and carry a mainly shrubby vegetation.
3. The flats with usually deep soils of sandy loam or loamy sand, or wind-blown Kalahari sand, which carry either a grass or a dwarf shrub vegetation.

These three different major types of habitat correspond to three major habitat-vegetation complexes, namely the riverine forest and woodland vegetation, the shrubby vegetation of the slopes and the non-shrubby vegetation of the flats. A few exceptions have to be accounted for, such as the Pentzio calcareae-Stipagrostietum acacietosum erioloba occurring on flats with deep well-drained Kalahari sand which should be included in the group "shrubby vegetation of the slopes". The *Brachiaria serrata-Elionurus argenteus* Community should be included in the group "non-shrubby vegetation of the flats" although this community, in exceptional cases, occurs on fairly steep south facing slopes. The Monechmatetum incani occurs in shrubby as well as in non-shrubby phases, so it should be included in two groups.

The various communities making up these three major habitat-vegetation complexes can be arranged according to their habitat in three parallel series from mesic to xeric in correspondence with the climatic gradient of the study area in particular. Neglecting the minor communities described in Chapters 5.1 and 5.7, the series as listed in Table 19 were obtained in this manner.

The shift in habitat of the various communities is in the first place as far as species composition is concerned, expected to be reflected in the character and differential species, because these are species whose ecological amplitudes restrict them to specific habitats in the study area. The autecology of the character and differential species is particularly important in this respect, although a detailed knowledge of the autecology of each of these species does not necessarily result in a detailed knowledge of the ecology of the community which they constitute (Odum, 1959; Westhoff, 1969). However, virtually no autecological information on the species occurring in the Upper Orange River area is available, but it is possible to assess a species on its general appearance as more or less mesophytic or xerophytic.

In the riverine forest and woodland vegetation the general climatic gradient from mesic to xeric is reflected in the leaves of the tree-layer (compare Chapter 5.1). In the most mesic part of the study area *Celtis africana* forms the tree-layer of the Rhoo-Diospyretum celtidetosum. Towards the drier part of the area the Rhoo-Diospyretum

TABLE 19 - Communities arranged along the mesic-xeric gradient

	Riverine forest and woodland		Shrubby vegetation of the slopes		Non-shrubby vegetation of the flats	
	Communities	Main structural types	Communities	Main structural types	Communities	Main structural types
Mesic	Rhoo-Diospyretum celtidetosum	deciduous forest	Rhamno-Roetum	evergreen/deciduous scrub to evergreen/deciduous steppe scrub	Brachiaria ser.-Elionurus arg. Eragrostis plana-Eragr. gumm.	seasonal short grass
			Mayteno polyac.-Oleetum afr. typicum Rhoo-Aloetum ferocis Blepharido-Rhoetum	evergreen forest to evergreen steppe forest to evergreen steppe scrub	Pentzia glob.-Eragrostis curv.	open evergreen dwarf scrub with closed ground cover
	Rhoo-Diospyretum acacietosum kar.	deciduous forest	Mayteno polyac.-Oleetum afr. chamareetosum Setario lind.-Buddlejetum sal.	evergreen steppe scrub/evergreen steppe savanna		
			Stachyo-Rhoetum Nanantho vitt.-Rhoetum	evergreen steppe scrub/evergreen steppe savanna	Hermannio coc.-Nestleretum conf. Osteospermetum leptolobi	evergreen dwarf steppe scrub/evergreen dwarf shrub steppe savanna
	Zizipho-Acacietum karroo	deciduous forest	Zizipho-Rhigozetum obovati	deciduous steppe scrub/deciduous steppe savanna		
			Pentzio calc.-Stipagrostietum acacietosum eriol.	evergreen steppe savanna	Enneapogono desv.-Stipagrostietum Pentzio calc.-Stipagrostietum typic.	evergreen dwarf shrub steppe savanna
			Melhanio rehm.-Hermannietum spin. Monechmatetum incani Nestlero min.-Pteronietum sord. stipagrostietosum cil.	deciduous steppe scrub/deciduous shrub steppe savanna	Monechmatetum incani Nestlero min.-Pteronietum sord. typicum	evergreen dwarf steppe scrub
Xeric			Eriocephalo-Eberlanzietum	deciduous shrub steppe savanna/deciduous desert scrub		

acacietosum karroo occurs, with *Acacia karroo* forming the tree-layer, and the Zizipho-Acacietum karroo is found in the driest part of the study area with *Acacia karroo* and *Ziziphus mucronata* as codominants in the tree-layer. The lower strata inside the riverine forest do not show the gradient from mesic to xeric, indicating that inside the forest this gradient barely exists. In the Rhoo-Diospyretum the most mesophytic species are *Rubia cordifolia, Cineraria lobata* and *Achyranthes aspera*, while in the Zizipho-Acacietum karroo these are *Setaria verticillata* and *Senecio burchellii*. The other species are all less mesophytic but they do not contribute in giving any one of the syntaxa a clearly more xeromorphic physiognomy than any other in the riverine forest and woodland vegetation.

Also, there is no clear change in structure in this vegetation which could have indicated an increase in xeric conditions in the down-river direction.

Thus, although the uppermost layers which are most exposed to the macroclimatic factors causing the gradient from mesic to xeric reflect this change in their leaf types, the moisture regime of the deep sandy levees is apparently favourable to such an extent that it can support a vegetation with the closed structure of a forest. Owing to this closed forest structure of the levee vegetation, the macroclimatic factors have only a small impact on the habitat inside the forest. Forest structure allows for the creation of its own internal habitat conditions which stay largely similar over its entire range. Mesophytic plants therefore occur in more or less similar quantities in all syntaxa of the riverine forest and woodland vegetation. It may thus be concluded that in this vegetation the moisture regime of the substrate is the strongest and most decisive environmental factor and not the complex of macroclimatic factors. In this sense the riverine forest and woodland represents an azonal vegetation type (Walter, 1954a). In accordance with this status of azonal vegetation type, the riverine forest and woodland is not divided by phytogeographical boundaries (compare Chapter 3). Apart from a relatively large amount of apophytes and neophytes, over its entire range in the study area it shows strong palaeotropic affinities, while no subdivisions present in the surrounding area divide the riverine vegetation.

In the mesic to xeric series of the shrubby vegetation of the slopes in the study area, fourteen syntaxa are involved. The most mesic is the Rhamno-Rhoetum occurring on the south-facing slopes in the area east of Aliwal North. The Rhamno-Rhoetum includes a considerable number of mesophytes among its character and differential species as well as species of a temperate humid distribution (compare Chapters 3 and 5.4).

Next in the series follow the other two Grewio-Rhoetalia erosae associations, the Rhoo-Aloetum ferocis and the Blepharido-Rhoetum, together with the Mayteno polyacanthae-Oleetum africanae typicum. These syntaxa occur either on north-facing slopes in the warm temperate, relatively humid, area upstream from Aliwal North, or on south-facing slopes or sheltered sites in the slightly drier area between Aliwal North and Colesberg (compare Chapter 5.4). The number of mesophytes in these communities has decreased markedly in comparison to the Rhamno-Rhoetum, but there are still mesophytes present, like *Senecio hieracioides* and particularly species in the order character and differential group of the Grewio-Rhoetalia erosae, such as *Melica decumbens, Ehrharta erecta, Berkheya discolor* and *Polygala amatymbica*. Others like *Rhynchelytrum repens, Aristida bipartita, Pavonia burchellii* and also *Grewia occidentalis* and *Celtis africana* apparently indicate relatively mesic conditions in the study area. At the same time the number of xeromorphic species increases in these communities, while in the Rhoo-Aloetum ferocis, succulents become significant. They possibly indicate the importance of hot and relatively dry conditions of its habitat during the daytime, when the sun radiation constitutes a salient environmental factor on these north-facing slopes.

The next link in the series is formed by the Mayteno polyacanthae-Oleetum africanae chamareetosum and the Setario lindenbergianae-Buddlejetum salignae. The former community occurs on less sheltered but still not strongly xeric sites in the area between Aliwal North and Colesberg, and the latter community on southerly or westerly facing slopes just below the summits of the mountains in the area downstream from Colesberg as far as the vicinity of Petrusville where it constitutes the least xeric habitat. The Mayteno polycanthae-Oleetum africanae chamareetosum apart from *Senecio hieracioides* contains no real mesophytes, although species like *Pelargonium aridum, Mohria caffrorum,* and a few others do not occur on hot and dry sites. In the Setario lindenbergianae-Buddlejetum salignae only *Solanum retroflexum* can be regarded as relatively mesophytic and the relatively xeromorphic species like *Buddleja saligna, Osyris lanceolata, Asparagus striatus* and *Cussonia paniculata* are significant in this association (compare Chapter 5.4).

Next in the series are the Stachyo-Rhoetum and the Nanantho vittati-Rhoetum, both mainly occurring on northerly facing slopes in the False Upper Karoo between Aliwal North and Petrusville. No real mesophytes are found in these associations and succulents and species with coriaceous, sclerophyllous and small leaves become important (compare Chapter 5.4).

The Zizipho-Rhigozetum obovati represents the next link. It occurs on hot, dry sites in the narrow valley trough downstream from Skurwekop and on the slopes of inselbergs on the flats west of Petrusville. Several species in this association occur more commonly in the False Upper Karoo and extend their most westward distribution into the arid zone here (compare Chapter 5.5). Most species have small, hairy or coriaceous to sclerophyllous leaves and succulents are not rare.

The penultimate link in the series is formed by the Pentzio calcareae-Stipagrostietum

acacietosum erioloba which occurs on deep Kalahari sand. The sand probably stores a considerable amount of water in its lower layers which is available for the trees and shrubs with deep root systems. These species, *Acacia erioloba* and *A. tortilis* subsp. *heteracantha*, possess microphyllous, slightly coriaceous leaves. The dwarf shrubs in this community are clearly xeromorphic, however, and grasses, which are only physiologically active during the short rainy season and whose aerial parts die away soon afterwards, are the most prominent species (compare Chapter 5.6).

In the Upper Orange River area the end link in the series from mesic to xeric is formed by the Melhanio rehmannii-Hermannietum spinosae, the Monechmatetum incani, the Nestlero minutae-Pteronietum sordidae stipagrostietosum ciliatae and the Eriocephalo-Eberlanzietum, all occurring downstream from Petrusville and mainly west of Hopetown. The species of all these communities show rather strong xeromorphic features, such as small, hairy and sclerophyllous leaves, strong spinosity, and succulence. Good examples are *Hermannia spinosa, Lasiocorys capensis, Blepharis mitrata, Barleria lichtensteiniana, Mestoklema tuberosum, Hoodia gordonii, Monechma incanum, Nestlera minuta forma, Pteronia sordida, Microloma massonii, Zygophyllum gilfillani, Eberlanzia spinosa, Aptosimum spinescens* (compare Chapter 5.5).

The gradient from mesic to xeric is thus clearly reflected in the species composition of the various shrubby communities of the slopes.

The gradient from mesic to xeric is also expressed in the structure of these various shrub communities although less marked than in the species composition. The series start with an evergreen to deciduous scrub or steppe scrub, followed by an evergreen forest or steppe forest formed by the Mayteno polyacanthae-Oleetum africanae typicum. The difference between the scrub and forest formations is just a matter of height. The next stage is an evergreen steppe scrub or evergreen steppe savanna, as represented by several Rhoetea erosae communities. Then follow the Pentzietea incanae communities as deciduous steppe scrub, deciduous shrub savanna or deciduous shrub steppe savanna, interrupted by the evergreen steppe savanna formed by the Pentzio calcareae-Stipagrostietum acacietosum erioloba, on deep Kalahari sand. The series is closed by the deciduous shrub steppe savanna or deciduous desert scrub formed by the Eriocephalo-Eberlanzietum. Thus a clear but inconspicuous gradient is shown from evergreen fairly dense vegetation to deciduous open vegetation.

The position of each community in this series is not simply determined by its distribution from east to west in the study area, and thus by macroclimatic factors alone, but as has been shown, is strongly influenced by the slope direction and sometimes by soil type and relative altitude. Hence, geological and geomorphic characteristics are indirectly involved. These characteristics together with the macroclimatic changes in the east-west direction, determine the relative position of the shrubby communities in the mesic-xeric gradient.

The shrubby communities show a clear phytogeographic subdivision. The Grewio-Rhoetalia erosae, occurring east of Bethulie, and in particular the Rhamno-Rhoetum, although basically Sudano-Zambesian in their floristic affinities, contain a considerable number of taxa with an Afro-montane and an Afro-montane-Cape distribution (compare Chapters 3 and 5.4). The remaining Rhoetea erosae communities are all clearly Sudano-Zambesian, although Karoo-Namib taxa and particularly species with a central type of distribution also occur. The Pentzieta incanae and the Pentzio calcareae-Stipagrostietum acacietosum giraffe, which belongs to the Stipagrostion, belong chorologically to the Karoo-Namib Region, but Sudano-Zambesian and centrally distributed taxa reach different degrees of importance in the various communities. In the Zizipho-Rhigozetum obovati these elements are of considerable importance, whereas they are virtually lacking in the Zygophyllion gilfillani and the Eriocephalo-Eberlanzietum. The Capensis element is negligible in all these shrubby communities (compare Chapters 3, 5.4, 5.5 and 5.6).

In the non-shrubby communities of the study area the series from mesic to xeric start with the *Brachiaria serrata-Elionurus argenteus* and the *Eragrostis plana-Eragrostis gummiflua* grassland Communities. Mesophytes and species widely distributed in the warm temperate humid zone commonly occur in these communities, for example *Eragrostis racemosa, E. capensis, Ajuga ophrydis*, and others (compare Chapter 5.2).

The *Pentzia globosa-Eragrostis curvula* Community comes next in the series. Although grasses still form the most conspicuous component in this community, karroid dwarf shrubs with small ericoid leaves start to play an important role as well (compare Chapter 5.2).

Then follow the dwarf shrub communities on loamy soils, the Hermannio coccocarpae-Nestleretum confertae and the Osteospermetum leptolobi, both occurring mainly between Aliwal North and Colesberg. In these associations the conditions of their habitats are well indicated by the xeromorphy of the karroid dwarf shrub species, which constitute the dominant growth form (compare Chapter 5.3-4).

The next link in the series is formed by the Stipagrostion communities of the Kalahari sand, the Enneapogono desvauxii-Stipagrostietum and the Pentzio calcareae-Stipagrostietum typicum. In these communities the karroid dwarf shrubs and the low xeromorphic deciduous shrub *Rhigozum trichotomum* are well represented, but the dominant growth form is constituted by grasses with a short physiologically active period during the rainy season and whose aerial parts die soon afterwards. Examples are *Enneapogon desvauxii, Stipagrostis obtusa* and *S. ciliata* (compare Chapter 5.6).

The series is closed in the study area by the Monechmatetum incani and the Nestlero minutae-Pteronietum sordidae typicum. In these open communities dwarf shrub species often spinous, with small, hairy or sclerophyllous leaves are again the most important constituents (compare Chapter 5.5).

The gradual shift from rather mesic to xeric conditions of the habitat is thus well reflected in the species composition of the non-shrubby communities.

The shift in habitats of the various communities is also shown in their structure, although again less marked than in their species composition. At the mesic beginning of the series, the vegetation consists of seasonal short grass, followed by open evergreen dwarf scrub with closed ground cover as represented by the *Pentzia globosa-Eragrostis curvula* Community. Then follow the False Upper Karoo communities as evergreen dwarf steppe scrub or evergreen dwarf steppe savanna. These formations are also formed by the more xeric Stipagrostion and Pentzietea incanae communities. The non-shrubby communities thus represent structurally a series from closed herbaceous vegetation to open dwarf steppe scrub, in which grasses are successively less prominent.

As in the series of the shrubby communities, the position in the mesic-xeric series of these non-shrubby communities is again not simply determined by their distribution in the east-west direction in the study area, which would mean solely by macroclimatic factors. Soil type can be a principal factor too, as is shown in the case of the Stipagrostion communities.

Phytogeographically these communities can again be subdivided meaningfully. The grassland communities occurring east of Aliwal North are real Sudano-Zambesian in their floristic affinities. The Hermannio coccocarpae-Nestleretum confertae and the Osteospermetum leptolobi, occurring downstream from these grassland communities, are also Sudano-Zambesian, but the Karoo-Namib element gradually increases in importance and taxa with a central type of distribution are numerous. The Stipagrostion and Pentzietea incanae communities of the non-shrubby series, occurring downstream from the escarpment near Petrusville, are real Karoo-Namib in their affinities. The Sudano-Zambesian element does not constitute a significant fraction here while centrally distributed taxa are well represented. Capensis affinities with any of the communities of this series are again negligible (compare Chapters 3 and 5).

From the pattern of phytogeographical boundaries through the shrubby communities as well as through the non-shrubby communities it is evident, that several boundaries of Acocks's (1953) veld types coincide with chorological boundaries, suggesting that veld types are phytogeographically meaningful.

Because the theory of approach and concepts and the methods applied in the present study have been amply discussed by Werger (1973b, 1974a, b) and need not be enlarged on here, only the question of the degree in which anthropogenic influences have determined the structure and floristic composition of the communities in the Upper Orange River area, requires a brief discussion.

No pertinent field work on this subject was carried out during the present survey but field observation and study of relevant literature as discussed in Chapter 2.6 allow some general conclusions. The floristically rich shrubby communities, which generally occur on the steeper slopes and are therefore not so easily accessible to sheep, are clearly least affected by the more than one century of continuous severe overgrazing. Most affected seem to be the Pentzio-Chrysocomion and the Stipagrostion communities. These communities are floristically rather poor, and are dominated over extensive areas by a single species: the Pentzio-Chrysocomion by the unpalatable *Chrysocoma tenuifolia* and the Stipagrostion often by the mostly defoliated shrub *Rhigozum trichotomum*. The Pentzietea incanae are frequently dominated by the shrub *Acacia mellifera* subsp. *detinens* and the eastern grassland communities by *Euryops annae*, both as a result of overgrazing.

The Pentzio-Chrysocomion, and the Stipagrostion in their *Rhigozum*-phases, represent typical convergent communities in a relation theory terminology (Van Leeuwen, 1966, 1970). According to the third basic relation of this theory the spatial monotony of these communities implies a temporal instability. This is well demonstrated by the change in species composition occurring in these communities when they are protected from severe grazing for a few seasons (compare Chapter 2.6). Within the study area the communities of the steep slopes which are nearly inaccessible to sheep, such as the Enneapogono scabri-Rhigozion obovati, and particularly the Indigofero spinescentis-Rhoion erosae communities, represent on the other hand divergent communities. The spatial diversity in these communities implies according to the same third basic relation of the relation theory a stability in time. The fact that these communities, particularly those belonging to the Indigofero spinescentis-Rhoion erosae, have presumably not changed in species composition to any important degree since the introduction of Merino sheep, demonstrates this point.

Summary

An account is given of the syntaxonomy and synecology of the vegetation of the Upper Orange River, South Africa. The study area is 656 km long, varying in width and measuring just over 3 000 km^2 in area. It covers grassland, open dwarf shrub and shrubby vegetation.

In Chapter 1 it is pointed out that the study was initiated as a result of the huge waterworks under construction along the Orange River, which will bring about considerable changes in due course. Some historical notes concerning the study area are made.

Chapter 2 discusses in some detail the physiographical factors of the area as well as human impact on the vegetation.

The gradient of the river fluctuates somewhat from place to place, but is 0,65 m/km on the average. The study area falls entirely in the regime of a summer rainfall climate, with a maximum precipitation during March and a minimum during June or July. Precipitation is mostly in the form of thunderstorms. The sunshine in the entire area is between 70 and 80% of the possible annual amount. The dominant wind direction for the area is between N and NW. There are considerable diurnal changes in most meteorological factors. Frost and snowfall can occur over the entire area, the latter rather infrequently, and both more often in the eastern than in the western part. It is emphasized that there is a major, complex gradient following the river course. In meteorological factors there is a decreasing gradient in average annual relative humidity and in precipitation which changes from over 600 mm in the east to less than 300 mm in the west, while there is an increasing gradient in temperature, particularly so in the average daily maxima of the warmest month, in cloudiness, in evaporation and in mean saturation deficit. This results in a gradient of climates from relatively humid, temperate tropical in the east, over a drier steppe climate to a dry sub-desert climate in the west. Due to topographical differences, which are more prominent in the east than in the west, there are considerable differences in meso- and microclimates within the study area.

In the east-west direction the river flows over successively older strata of the Karoo System, first of the Stormberg Series, then of the Beaufort and Ecca Series and finally of the Dwyka Series which are locally interrupted by the Precambrian Ventersdorp lavas. The succession is frequently interrupted by dolerite intrusions. Tertiary to recent aeolian Kalahari sand and calcrete accumulations occur in the westernmost part of the study area, while alluvial deposits occur locally all along the river course.

Also geomorphologically the landscape changes from a rather dissected countryside in the east to the flat monotonous landscape with isolated inselbergs and scattered pans in the west.

Soils in the study area vary from the Highveld prairie soils in the east, over the solonetzic soils to the sandy and calcareous desert soils in the west. Shallow lithosols are common throughout the study area.

In the vegetation a gradient from grassland over open dwarf shrub and grass vegetation to an open dwarf shrub steppe is covered by the study area in an east-west direction. Slopes are usually covered by an open shrubby vegetation, while on Kalahari sand in the western part of the study area an open tree savanna occurs locally. A riverine forest and woodland vegetation fringes the river over virtually the entire study area.

Land-use in the study area is mainly mixed farming in the east and extensive stock farming in the west.

In Chapter 3 it is pointed out that a major chorological boundary runs through the area, namely the boundary between the Sudano-Zambesian Region and the Karoo-Namib Region, which traverses the valley just downstream from Petrusville, coinciding with the boundary between dissected and flat countryside. In the easternmost part of the area the Afro-montane element is well represented. The Cape element is virtually lacking in the entire Upper Orange River valley. An enumeration of some species occurring in the area with Afro-montane, Afro-montane-Cape, Capensis, Sudano-Zambesian, Karoo-Namib and "Central" distribution patterns is given. Also some species with distribution patterns not exemplifying this chorological classification of the area are listed.

In Chapter 4 a brief summary of the methods used is given.

A description of the plant communities, their structure, habitat, distribution within the study area and syntaxonomical rank is given in Chapter 5. The riverine forest and woodland vegetation covering the levees of the Upper Orange River is described in two associations, the Rhoo-Diospyretum and the Zizipho-Acacietum karroo belonging to the same alliance, the Diospyrion lycioidis. The Rhoo-Diospyretum is divided into two subassociations, the celtidetosum and the acacietosum karroo, and also an *Acacia karroo* variant of the celtidetosum is recognized. These syntaxa occur in a geographical sequence, probably

due to the climate gradient in the area. Some riverine communities of minor extent and importance are also briefly described. Three communities are distinguished in the grassland vegetation of the eastern part of the study area but they are not ranked syntaxonomically.

One association, the Hermannio coccocarpae-Nestleretum confertae, with three subassociations, the aptosimetosum marlothii, the eragrostietosum curvulae and the oropetietosum, as well as a variant with *Eragrostis lehmanniana* is described from the dwarf shrub vegetation of the plains of the False Upper Karoo and the differences in habitat are indicated. A provisional description is given of the alliance Pentzio- Chrysocomion, to which this association belongs.

The shrubby communities of the slopes in the eastern grassland area and the False Upper Karoo all belong to the class Rhoetea erosae in which two orders have been recognized. The Grewio-Rhoetalia erosae occur on mesic sites, mainly in the area east of Aliwal North, and comprise three associations: the Rhamno-Rhoetum on southerly facing slopes, the Rhoo-Aloetum ferocis on northerly facing slopes and the Blepharido-Rhoetum on mesic sites near Aliwal North. The first two associations are combined in the alliance Indigofero spinescentis-Rhoion erosae. The Afro-montane and the Afro-montane-Cape elements are well represented in the Grewio-Rhoetalia erosae, particularly in the Rhamno-Rhoetum. The Rhoetalia ciliato-erosae comprise most of the shrubby communities between Aliwal North and Petrusville and include five associations: the Osteospermetum leptolobi on gentle sloping terrain with shallow soils on sandstones and mudstones, with the subassociations typicum and aptosimetosum marlothii; the Stachyo-Rhoetum, mainly on northerly facing dolerite slopes, with the subassociations polygaletosum and hermannietosum vestidae and, near Petrusville, a variant with *Salvia namaensis*; the Nanantho vittati-Rhoetum, mainly on northerly facing sandstone slopes near Bethulie; the Mayteno polyacanthae-Oleetum africanae, largely confined to steep southerly facing dolerite slopes, with the subassociations typicum and chamareetosum; and the Setario lindenbergianae-Buddlejetum salignae on dolerite slopes just below the summits in the area around Petrusville. The first three associations are combined into the alliance Hibisco marlothiani-Rhoion erosae. The western boundary of the Rhoetea erosae coincides in the study area with the boundary between the Sudano-Zambesian and Karoo-Namib Regions.

The shrub and dwarf shrub communities on rocky soils downstream from Petrusville belong largely to the class Pentzietea incanae comprising five associations: the Zizipho-Rhigozetum obovati, mainly on dolerite slopes between Skurwekop and Hopetown, with the subassociations cheilanthetosum ecklonianae and inops; the Melhanio rehmannii-Hermannietum spinosae on andesitic lava slopes downstream from Hopetown; the Monechmatetum incani on alkaline sites where some concentration of run-off occurs, with the subassociations typicum and pentzietosum calcareae; the Nestlero minutae -Pteronietum sordidae on calcrete-rich substrates downstream from Orania, with the subassociations typicum and stipagrostietosum ciliateae; and the Eriocephalo-Eberlanzietum on nearly level, slightly acid, loamy sands between Skurwekop and Hopetown. The Zizipho-Rhigozetum obovati and the Melhanio rehmannii-Hermannietum spinosae are combined into the alliance Enneapogono scabri-Rhigozion obovati; the Monechmatetum incani and the Nestlero minutae-Pteronietum sordidae into the Zygophyllion gilfillani. Both alliances are combined into the order Pentzio incanae-Rhigozetalia trichotomi.

Two associations occur in the study area on Kalahari sand: the Enneapogono desvauxii-Stipagrostietum on slightly loamy sand, and the Pentzio calcareae-Stipagrostietum on pure Kalahari sand overlying calcrete. The latter association comprises the subassociations typicum and acacietosum erioloba. Both associations, together with some associations described from the southern Kalahari, can be combined into the alliance Stipagrostion which is provisionally described.

Some communities of minor extent in the study area are briefly described at the end of Chapter 5 without attempting to rank them syntaxonomically.

In Chapter 6 an integrated outline of the ecological and syntaxonomic gradient in the study area is given, emphasizing climatic changes and floristic and structural features in the communities. Based on the moisture regime of the soil, three parallel series of communities from mesic to xeric are represented and the expression of habitat conditions in species composition and community structure is discussed. Finally, brief remarks are made on the relation between the impact of mismanagement of the vegetation and diversity in landscape and vegetation.

Opsomming

Die studie handel oor 'n sintaksonomiese en sinekologiese ondersoek van die plantegroei van die dal van die Bo-Oranjerivier in Suid-Afrika. Die ondersoekgebied is 656 km lank, varieer in breedte en beslaan ietwat meer as 3 000 km². Dit sluit grasveld, dwergstruik- en struikagtige plantegroei in.

In Hoofstuk 1 word verduidelik dat die ondersoek onderneem is na aanleiding van die enorme waterwerke wat in die Oranjeriviergebied in aanbou is en wat binne afsienbare tyd aansienlike veranderings teweeg sal bring. Die hoofstuk bevat ook enkele geskiedkundige besonderhede wat betrekking op die gebied het.

Die fisiografiese faktore in die ondersoekgebied en die invloed van menslike aktiwiteit op die plantegroei word in Hoofstuk 2 bespreek. Die gradiënt van die rivier wissel in 'n mate van plek tot plek, maar is gemiddeld 0,65 m/km. Die ondersoekgebied val geheel en al in die somerreënstreek. Maart is die maand met die maksimum neerslag en die minimum is in die maande Junie en Julie. Die neerslag is gewoonlik in die vorm van donderbuie. Die sonskyn is oor die hele gebied tussen 70 en 80 persent van die moontlike jaarlikse totaal en die oorheersende windrigting is tussen N en NW. Daar is aansienlike daaglikse verskille in meeste van die meteorologiese faktore. Oor die hele gebied kan ryp en af en toe ook sneeu voorkom, hoewel dit meer algemeen in die oostelike as in die westelike deel is. Nadruk word gelê op die belangrike, komplekse gradiënt wat daar van oos na wes heers. Wat die meterologiese faktore betref, is daar 'n afnemende gradiënt in gemiddelde jaarlikse relatiewe lugvogtigheid en in neerslag, wat verskil van meer as 600 mm in die ooste tot minder as 300 mm in die weste van die ondersoekgebied. 'n Toenemende gradient in temperatuur, veral wat die gemiddelde daaglikse maksima vir die warmste maand betref, in wolkbedekking, in verdamping en in gemiddelde versadigingstekort kom ook in die gebied voor. Daar is dus 'n klimaatsgradiënt wat wissel van relatief vogtig gematig-tropies in die ooste, deur 'n droër steppeklimaat tot 'n droë woestynagtige klimaat in die weste. As gevolg van verskille in topografie, wat in die ooste meer prominent is as in die weste, is daar aansienlike verskille in meso- en mikroklimaat binne die ondersoekgebied.

In die oos-wesrigting stroom die rivier oor opeenvolgende ouer afsettings van die Karoo-sisteem, naamlik eerstens van die Stormbergserie, daarna van die Beaufort- en Eccaserie en uiteindelik van die Dwykaserie, wat plek-plek deur Prekambriese Ventersdorp-lawa-afsettings onderbreek word. In al die afsettings kom daar dikwels dolerietindringings voor. Tersiêre en resente eoliese afsettings van Kalaharisand en kalkreet kom in die westelike deel van die ondersoekgebied voor, en alluviale afsettings word plek-plek langs die rivier aangetref. Geomorfologies verander die landskap van taamlik gebroke in die oostelike dele tot plat eentonig met alleenstaande koppies en verspreide panne in die weste.

Binne die ondersoekgebied verskil die gronde van die Hoëveldse prêriegronde in die ooste, oor die solonetsgronde tot die sanderige en kalkryke woestyngronde in die weste. Vlak litosols kom algemeen voor. Die plantegroei wissel van oos na wes van grasveld, oor oop dwergstruik en grasse tot 'n oop dwergstruiksteppe. Die hange is gewoonlik begroei met 'n oop struikagtige plantegroeitipe en op die Kalaharisand in die westelike deel van die ondersoekgebied kom daar hier en daar 'n oop boomsavanne voor. Oor byna die hele ondersoekgebied groei daar 'n stroomoewerbos en boomveldplantegroei langs die rivier.

Bodembenutting binne die ondersoekgebied verskil van hoofsaaklik gemengde boerdery in die ooste tot ekstensiewe veeboerdery in die weste.

Die fitogeografie van die ondersoekgebied word in Hoofstuk 3 kortliks bespreek. 'n Belangrike fitogeografiese grens, naamlik dié tussen die Sudano-Sambesiese en die Karoo-Namib-streke kruis die ondersoekgebied net onderkant Petrusville. Hierdie grens val saam met die grens tussen die gebroke en die plat landskappe. In die mees oostelike deel van die ondersoekgebied is die Afro-montane element goed verteenwoordig, terwyl die Kaapse element vrywel geheel en al ontbreek in die hele Bo-Oranjegebied. Daar word 'n lys gegee van sekere soorte wat binne die ondersoekgebied voorkom en wat Afro-montane, Afro-montaan-Kaapse, Kaapse, Sudano-Sambesiese, Karoo-Namib- en "Sentrale" verspreidingspatrone vertoon. Daar word ook 'n lys van soorte gegee waarvan die verspreidingspatrone nie as voorbeelde vir hierdie plantegeografiese klassifikasie kan dien nie.

In Hoofstuk 4 word die metodes wat in hierdie ondersoek gebruik is kortliks aangedui.

In Hoofstuk 5 word 'n beskrywing van die plantegemeenskappe, hul struktuur, habitat, verspreiding binne die ondersoekgebied en hul sintaksonomiese rang gegee.

Die galerybos, wat op die oewerwalle van die Bo-Oranje groei, word as twee assosiasies beskryf, naamlik die Rhoo-Diospyretum en die Zizipho-Acacietum karroo. Hulle behoort tot

dieselfde verbond, die Diospyrion lycioidis. Die Rhoo-Diospyretum is onderverdeel in twee subassosiasies, die celtidetosum en die acacietosum karroo, en binne die celtidetosum word nog 'n variant met *Acacia karroo* onderskei. Hierdie sintaksa kom in 'n geografiese volgorde voor, wat waarskynlik deur die klimaatsgradiënt binne die gebied veroorsaak word. Enkele rivier oewergemeenskappe wat 'n beperkte verspreiding en belangrikheid het, word ook kortliks beskryf.

In die grasveld van die oostelike deel van die ondersoekgebied is drie gemeenskappe onderskei. Hulle is egter nie in die sintaksonomiese sisteem geplaas nie.

Van die dwergstruikplantegroei van die vlaktes van die Skynkaroo is slegs een assosiasie beskryf, die Hermannio coccocarpae-Nestleretum confertae, met drie subassosiasies, die aptosimetosum marlothii, die eragrostietosum curvulae en die oropetietosum, en 'n variant met *Eragrostis lehmanniana*. Hulle onderlinge habitatsverskille word bespreek. 'n Voorlopige beskrywing van die verbond Pentzio-Chrysocomion, waartoe bogenoemde assosiasie behoort, word gegee.

Die struikagtige plantegroei op die hange in die oostelike grasveldstreek en in die Skynkaroo behoort geheel en al tot die klas Rhoetea erosae, waarbinne twee ordes onderskei word. Die Grewio-Rhoetalia erosae kom op mesiese groeiplekke voor, hoofsaaklik oos van Aliwal-Noord, en omvat drie assosiasies: die Rhamno-Rhoetum op suidfronthange, die Rhoo-Aloetum ferocis op noordfronthange en die Blepharido-Rhoetum op effens mesiese groeiplekke in die omgewing van Aliwal-Noord. Die eersgenoemde twee assosiasies is in die verbond Indigofero spinescentis-Rhoion erosae verenig. Die Afro-montane en die Afro-montaan-Kaapse elemente is in die Grewio-Rhoetalia erosae goed verteenwoordig, veral in die Rhamno-Rhoetum. Die Rhoetalia ciliato-erosae omvat byna al die struikagtige gemeenskappe in die streek tussen Aliwal-Noord en Petrusville en sluit vyf assosiasies in: die Osteospermetum leptolobi op effens hellende terrein met vlak gronde op sandsteen en moddersteen, met die subassosiasies typicum en aptosimetosum marlothii; die Stachyo-Rhoetum, wat hoofsaaklik op noordfrontdoleriethange voorkom, met die subassosiasies polygaletosum en hermannietosum vestidae en, in die omgewing van Petrusville, 'n variant met *Salvia namaensis*; die Nanantho vittati-Rhoetum wat veral op noordfrontsandsteenhange in die nabyheid van Bethulie voorkom; die Mayteno polyacanthae-Oleetum africanae, wat hoofsaaklik beperk is tot steil suidfrontdoleriethange, met die subassosiasies typicum en chamareetosum; en die Setario lindenbergianae-Buddlejetum salignae wat in die nabyheid van Petrusville op doleriethange net onderkant die kruine van die berge voorkom. Die eerste drie assosiasies is verenig in die verbond Hibisco marlothiani-Rhoion erosae. Die westelike grens van die Rhoetea erosae val in die ondersoekgebied saam met die grens tussen die Sudano-Sambesiese en Karoo-Namib-streke.

Die struik- en dwergstruikgemeenskappe op klipperige grond stroomafwaarts van Petrusville behoort hoofsaaklik tot die klas Pentzietea incanae, wat vyf assosiasies insluit: die Zizipho-Rhigozetum obovati, wat veral op doleriethange in die gebied tussen Skurwekop en Hopetown voorkom, met die subassosiasies cheilanthetosum ecklonianae en inops; die Melhanio rehmannii-Hermannietum spinosae op andesitiese lawahange stroomafwaarts van Hopetown; die Monechmatetum incani op alkaliese plekke waar afloop in 'n mate gekonsentreer is, met die subassosiasies typicum en pentzietosum calcareae; die Nestlero minutae-Pteronietum sordidae op kalkryke subtrate stroomafwaarts van Orania, met die subassosiasies typicum en stipagrostietosum ciliateae; en die Eriocephalo-Eberlanzietum op bykans nie-hellende, effens suur, leemsanderige groeiplekke tussen Skurwekop en Hopetown. Die Zizipho-Rhigozetum obovati en die Melhanio rehmannii-Hermannietum spinosae is in die verbond Enneapogono scabri-Rhigozion obovati verenig; die Monechmatetum incani en die Nestlero minutae-Pteronietum sordidae in die verbond Zygophyllion gilfillani. Beide verbonde is verenig in die orde Pentzio incanae-Rhigozetalia trichotomi.

Binne die ondersoekgebied kom daar twee assosiasies op Kalaharisand voor, die Enneapogono desvauxii-Stipagrostietum op effens lemerige sandgrond, en die Pentzio calcareae-Stipagrostietum op suiwer Kalaharisand wat oor kalkreet lê. Die laasgenoemde assosiasie omvat die subassosisasies typicum en acacietosum erioloba. Die twee assosiasies kan met 'n aantal vroeër beskrewe assosiasies, wat in die suidelike Kalahari voorkom, in die verbond Stipagrostion verenig word. Hierdie verbond is voorlopig beskryf.

Enkele gemeenskappe, wat slegs klein oppervlaktes in die ondersoekgebied beslaan, word aan die einde van Hoofstuk 5 kortliks beskryf maar nie sintaksonomies gerangskik nie.

In Hoofstuk 6 word daar 'n geïntegreerde beeld van die ekologiese en sintaksonomiese gradiënt in die ondersoekgebied gegee, waarin klem gelê word op die klimaatsveranderinge en die floristiese en strukturele kenmerke van die gemeenskappe. Op die basis van die voghuishouding van die gronde word die gemeenskappe in drie parallelle series van mesies tot xeries gerangskik. Die wyse waarop hierdie series die habitatstoestande in soortesamestelling en gemeenskapstruktuur weerspieël, word bespreek.

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Appendices

1. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 4 (DIOSPYRION LYCIOIDIS)

Althernanthera pungens 512:+;516:+
Argemone subsusiformis 420:1; 489:+
Asparagus denudatus 235:+
Asparagus laricinus 235:+; 223:+
Ballota africana 35:1; 388:1
Boscia albitrunca 489:+
Buddleja salviifolia 250:+
Chloris virgata 454:+
Convolvulus boedeckerianus 35:+
Cynodon hirsutus 327:2b
Ehretia rigida 133:+
Enneapogon desvauxii 101:1
Equisetum ramosissimum 162:1
Eragrostis curvula 171:1;105:r
Hebenstreitia dentata 5:r
Hertia pallens 154:+
Leucas martinicensis 398:1; 489:+
Maytenus heterophylla 207:+; 149:+
Oenothera stricta 5:+
Olea africana 189:r; 312:r
Panicum laevifolium 448:+
Pavonia burchellii 506:1
Pentzia calcarea 516:r
Phragmites australis 162:+
Phytolacca heptandra 118:+
Pollichia campestris 347:+; 493:+
Psilocaulon absimile 420:+
Rhus lancea 448:2b
Rhus undulata var. *tricrenata* 301:1
Salix babylonica 200:+
Salix capensis 415:+
Salsola kali 427:+
Selago albida 50:1
Solanum incanum 418:+
Solanum supinum 482:+
Talinum caffrum 215:+; 56:+
Tapinanthus oleifolius 506:+
Tragus berteronianus 454:+
Verbena bonariensis 250:+
Verbesina encelioides var. *encelioides* 493:1
Withania somnifera 207:+; 199:+
Xanthium spinosum 502:+
Xanthium strumarium 454:+

2. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 8 (EASTERN GRASSLANDS)

Aloinopsis spec. 213:r
Argyrolobium pauciflorum 239:+
Asclepias fruticosa 229:r
Blepharis integrifolia 224:+
Eustachys mutica 213:+
Galenia secunda 220:+
Geigeria filifolia 214:+
Gerbera viridifolia 274:+
Gnidia polycephala 205:+
Harpochloa falx 251:+
Helichrysum latifolium 274:+
Helichrysum rosum 251:+
Hermannia quartiniana 236:+
Hibiscus pusillus 242:+
Indigofera bifrons 271:+
Koeleria cristata 239:+
Lasiospermum bipinnatum 246:1
Lessertia pauciflora 205:+
Lightfootia denticulata 229:+; 213:+
Linum thunbergii 251:+
Lycium cinereum 205:+
Melolobium microphyllum 239:+
Monsonia biflora 214:+
Nenax microphylla 224:+
Nolletia ciliaris 239:+
Panicum stapfianum 246:+
Pelargonium sidifolium 220:+
Pennisetum sphacelatum 246:+
Polygala amatymbica 236:+
Rhus erosa 225:+
Rhus undulata var. *tricrenata* 225:+
Schizoglossum capense 205:+
Schistostephium crataegifolium 239:+
Senecio inornatus 239:+
Senecio latifolius 239:+
Senecio retrorsus 260:+
Sonchus dregeanus 220:+
Stapelia flavirostris 257:+
Striga bilabiata 251:+
Sutera caerulea 234:+
Sutera kraussiana 213:+
Triraphis andropogonoides 232:+
Vahlia capensis 214:+
Vernonia oligocephala 274:+
Zaluzianskya capensis 251:+

3. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 9 (HERMANNIO COCCOCARPAE-NESTLERETUM CONFERTAE)

Atriplex semibaccata 163:+; 546:r
Barleria rigida 287:+
Berkheya discolor 212:+
Blackiella inflata 282:+
Blepharis villosa 287:+
Brachiaria serrata 180:+
Chascanum pinnatifidum 201:r; 40:+
Chasmatophyllum musculinum 146:+
Cineraria lobata 22:+
Commelina africana 196:+; 154:+
Crassula schimperi var. *lanceolata* 155:r; 147:1
Crassula setulosa 555:r
Cymbopogon plurinodis 217:1; 555:r; 191:+
Cyphocarpha angustifolia 277:+; 326:+
Dianthus basuticus subsp. *basuticus* 217:+
Dicoma macrocephala 287:+
Digitaria eriantha 212:+; 180:+; 555:+
Eriocephalus pubescens 326:2a
Euphorbia clavarioides 255:+
Eustachys mutica 175:+
Galenia secunda 181:+; 164:r; 147:r
Helichrysum lucilioides 282:+
Heliotropium ciliatum 1:+
Hermannia depressa 217:r; 212:1; 184:+
Hermannia pulchra 280:+
Hermannia pulverata 546:+
Hermannia resedaefolia 4:+; 1:r
Heteropogon contortus 155:+; 307:r
Kohautia amatymbica 40:1; 103:1; 59:+
Lightfootia denticulata 40:+; 103:+; 110:+
Lithospermum cinereum 67:r
Lotononis laxa 139:+; 19:1
Lotononis tenella 279:r; 326:+; 24:+
Lycium pilifolium 542:2a
Monsonia angustifolia 175:+
Nanathus vittatus 128:+
Nestlera prostrata 326:+; 546:1
Nolletia ciliaris 196:+
Osteospermum leptolobum 19:+; 69:+
Panicum coloratum 73:1
Pegolettia retrofracta 283:1
Pelargonium fumarioides 537:+
Pentzia spinescens 134:1

Phymaspermum parvifolium 282:+; 157:+
Plinthus sericeus 22:3
Polygala leptophylla 318:+; 283:+; 117:+
Polygala uncinata 100:r
Psammotropha mucronata 280:+; 282:+
Rhus ciliata 279:+
Ruschia spec. 202:+
Setaria flabellata 175:+
Sporobolus discosporus 69:+; 84:+
Sporobolus ludwigii 73:+
Stachys burchelliana 147:+
Stipagrostis obtusa 279:2a; 326:2a
Sutera albiflora 70:+; 40:1
Sutera aurantiaca 212:+
Tetragonia arbuscula 12:+
Thesium spartioides 139:+
Tragus berteronianus 546:1; 551:+

4. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 10 (GREWIO-RHOETALIA EROSAE)

Ajuga ophrydis 259:+; 221:+
Aloe grandidentata 266:+
Anacampseros lanigera 216:+; 170:+
Aptosimum depressum 172:+; 170:+
Aristida adscensionis 233:+
Asclepias fruticosa 264:+
Asparagus asparagoides 237:+
Asparagus microraphis 243:+
Asplenium adiantum-nigrum 230:+; 240:+
Blechnum australe 268:1
Blepharis transvaalensis 172:r
Bowkeria verticillata 267:4
Buddleja salviifolia 267:+; 243:1; 230:+
Centella coriaceae 241:+
Ceterach cordatum 273:+; 254:+
Chamarea capensis 206:+
Cineraria aspera 206:r
Cineraria lobata 243:+; 238:+; 230:+
Cineraria mollis 243:+
Convolvulus boedeckerianus 256:+
Conyza podocephala 221:+; 174:+
Crabbea hirsuta 247:+; 245:+
Crassula muscosa var. *muscosa* 197:+
Crassula capitella subsp. *nodulosa* 228:+; 238:+
Cymbopogon excavatus 245:2b; 233:1
Cynoglossum hispidum 245:+
Dicoma anomala 264:+; 222:+; 219:+
Eragrostis chloromelas 536:+; 556:+
Eragrostis gummiflua 221:r; 241:+
Eragrostis superba 230:+
Erica caffra 240:2b
Euphorbia clavarioides 265:+; 170:+
Euphorbia striata 238:+
Euryops floribundus 243:+
Falkia repens 266:+
Felicia hyssopifolia 243:2b; 230:+
Festuca caprina 243:+
Festuca longipes 264:+; 238:+
Gnidia capitata 228:+; 222:+
Gnidia microcephala 200:+; 238:+
Hebenstreitia fruticosa 240:+
Helichrysum caespititium 268:+
Helichrysum ericifolium 270:+; 248:+; 221:+
Helichrysum infaustum 258:+
Helichrysum rugulosum 264:+; 269:+
Helichrysum setosum 259:+; 240:+
Helichrysum subglomeratum 270:+
Helichrysum zeyheri 256:+
Hermannia coccocarpa 179:+
Huernia spec. 254:+
Leonotis mollis 261:+
Leucophrys mesocoma 211:r
Leucosidea sericea 179:+; 243:2b
Linum thunbergii 536:+
Lippia javanica 242:+
Listia heterophylla 221:+; 174:+
Lithospermum affine 259:+
Lotononis laxa 187:+; 170:+
Lotononis tenella 231:+; 221:+
Massonia bowkeri 268:+
Maytenus undata 233:r; 231:1
Medicago aschersoniana 233:+
Melolobium microphyllum 187:+; 200:+
Merxmuellera disticha 226:+
Metalasia muricata 238:+
Microchloa caffra 265:+
Miscanthidium sorghum 230:+
Nananthus spec. 172:+
Nolletia ciliaris 219:+; 269:+
Oenothera indecora 230:+
Oenothera rosea 233:r
Panicum stapfianum 536:+
Pegolettia retrofracta 170:1
Pelargonium aridum 254:+; 197:+
Pelargonium cardiophyllum 179:+
Pelargonium myrrhifolium 221:+
Peucedanum connatum 536:+
Phyllanthus maderaspatensis 185:+; 172:+
Phymaspermum aciculare 209:+
Polygala uncinata 536:+
Printzia polifolia 210:+
Pterothrix spinescens 211:+
Rhigozum obovatum 209:+
Rhus dregeana 243:+; 230:1
Rhynchosia adenodes 221:+; 179:+
Rhynchosia nervosa 231:+
Rosa rubiginosa 248:1
Rubia cordifolia 268:+; 248:+; 536:r
Rubus cuneifolius 268:+; 248:+
Rubus ludwigii 238:+; 233:+
Salsola glabrescens 203:+
Schistostephium crataegifolium 238:+; 247:+; 245:+
Senecio burchellii 206:r
Senecio inornatus 238:+
Solanum incanum 233:+
Sutera aurantiaca 243:r
Sutera caerulea 238:+
Sutera griquensis 268:+
Thesium spartioides 170:+
Trachypogon spicatus 240:+
Trichodiadema pomeridianum 536:+; 174:r; 170:+
Venidium microcephalum 259:+; 237:+; 268:2a
Withania somnifera 267:1; 233:+
Zaluzianskya capensis 238:+

5. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 11 (RHOETALIA CILIATO-EROSAE)

Acacia mellifera subsp. *detinens* 351:+
Achyranthes aspera 552:+; 98:+
Aloinopsis spec. 541:+; 313:+; 32:2a
Anacampseros rufescens 173:+
Antizoma capensis 132:+; 130:+
Argemone subfusiformis 290:r
Asparagus setaceus 97:+; 38:+
Atriplex semibaccata 108:r; 324:+; 29:r
Berkheya radula 552:+
Boophane disticha 338:+
Boscia albitrunca 292:r; 299:r; 324:+
Caralluma lutea 549:+
Cenchrus ciliaris 173:1; 351:+; 545:2a
Ceterach cordata 115:1
Chasmatophyllum musculinum 148:+
Cheilanthes depauperata 89:+
Chloris virgata 335:r; 544:+
Cineraria lobata 550:+; 127:r; 29:+
Clematis brachiata 176:r; 136:r
Cleome angustifolia 286:+
Commelina africana 153:+; 98:+; 148:+
Conyza podocephala 153:+
Crassula tetragona subsp. *acutifolia* 51:+; 77:1
Crassula cooperi 286:+; 290:+
Crassula muscosa var. *muscosa* 541:+
Crassula schimperi var. *schimperi* 90:+
Cyperus usitatus 148:+

Dicoma anomala 176:+
Dimorphotheca cuneata 111:+; 62:+; 51:1
Enneapogon scaber 292:+; 299:+
Eragrostis nindensis 544:+; 538:+
Euphorbia mauritanica 188:+; 332:+; 331:2a
Euphorbia rectirama 336:+; 334:2a
Euphorbia rhombifolia 168:+
Euryops annae 89:2b
Gnidia capitata 549:+
Helichrysum aureum 127:r
Helichrysum cerastioides 544:+
Heliotropium ciliatum 49:1
Hermannia depressa 552:+
Hermannia filifolia 152:r; 150:2a
Hermannia resedaefolia 3:r; 130:+
Heteromorpha arborescens 38:+
Hibiscus aethiopicus 111:+; 115:+
Huernia spec. 148:+
Ifloga caespitosa 286:+
Indigofera bifrons 543:+
Indigofera spinescens 173:+
Ipomoea crassipes 550:+; 176:+
Kalanchoe paniculata 151:+
Kalanchoe thyrsiflora 334:+; 87:+; 538:+; 333:+
Koeleria cristata 176:+; 190:+
Kohautia amatymbica 303:+
Lasiosiphon burchellii 92:1; 93:1
Leucophrus mesocoma 176:+
Lightfootia denticulata 176:+
Linum thunbergii 153:+
Listia heterophylla 188:+
Lithospermum cinereum 37:+
Lotononis brachyloba 368:+
Lotononis tenella 77:+; 303:r
Lycium hirsutum 97:r
Melianthus comosus 115:r
Melolobium obcordatum 29:+
Microloma massonii 322:+
Monsonia angustifolia 547:+; 538:+
Myrsine africana 188:1
Nemesia fruticans 305:+; 324:1
Nemesia hanoverica 336:+
Nestltera minuta 319:+
Pavonia burchellii 138:r; 98:1
Peliostomum leucorrhizum 292:+; 299:+; 82:+
Pellaea quadripinata 539:+
Pentzia incana 368:2a; 43:1
Phaeoptilum spinosum 368:+
Piloselloides hirsuta 552:+; 115:+
Polygala asbestina 368:+; 29:+
Polygala hottentotta 338:+
Polygala spec. (Werger 1084) 543:+; 62:1
Rhamnus prinoides 188:+
Rhigozum trichotomum 380:1
Rhus viminalis 343:r
Rhynchosia confusa 541:1
Rubia cordifolia 77:r
Ruschia spec. 549:+; 62:1
Sarcostemma viminale 541:+; 304:+; 129:1
Scabiosa columbaria 29:1
Schizoglossum linifolium 121:+
Selago zeyheri 83:+
Senecio burchellii 343:+
Setaria flabellata 99:+
Setaria verticillata 319:1
Silene undulata 108:+
Solanum incanum 296:+
Stapelia olivacea 290:+
Stipagrostis zeyheri subsp. *sericans* 3:2b; 538:1
Sutera caerulea 57:r
Sutherlandia humilis 541:+
Thesium hystrix 368:+
Titanopsis spec. 62:+
Tragus berteronianus 545:+; 550:+
Trichoneura grandiglumis 535:+; 176:+
Turbina oenotheroides 333:+
Walafrida geniculata 343:+; 290:+
Withania somnifera 336:+; 98:+; 538:+
Zinnia peruviana 539:+

6. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 12 (PENTZIETEA INCANAE)

Adromischus rupicola 300:+
Aizoon burchellii 519:+
Aizoon schellenbergii 481:+; 488:+
Aloe hereroensis 344:1
Anacampseros lanigera 432:+
Aptosimum lineare 497:+; 428:+
Argyrolobium pauciflorum 346:+
Asparagus capensis 532:+
Asparagus racemosus 570:+; 503:+
Chloris virgata 422:+; 346:+
Cleome angustifolia subsp. *diandra* 302:1; 340:+; 300:1
Commicarpus pentandrus 453:+
Convolvulus boedeckerianus 437:+
Cotyledon decussata-orbiculata compl. 360:1; 344:+
Crassula tetragona subsp. *acutifolia* 473:+
Crassula muscosa var. *muscosa* 300:+; 530:+; 470:+
Crassula setulosa 457:1
Crassula schimperi var. *schimperi* 340:+
Cyperus usitatus 532:1; 464:+
Cypholepis yemenica 478:+; 510:+; 483:+
Dianthus basuticus subsp. *basuticus* 358:1; 457:1
Diospyros lycioides subsp. *lycioides* 302:1; 453:+; 409:+
Drosanthemum spec. 354:+
Eragrostis bicolor 431:+; 498:+; 464:+
Eragrostis brizantha 515:+
Eragrostis curvula 358:+; 346:+; 520:+
Eragrostis echinochloidea 529:+; 475:+; 519:+
Euclea crispa 302:+; 386:+
Euclea undulata 425:1
Euphorbia arida 430:+
Euphorbia rhombifolia 360:2b; 410:+
Felicia filifolia 352:+; 371:+
Fockea angustifolia 371:+
Galenia pubescens 492:+
Helichrysum ericifolium 409:+; 399:r
Helichrysum zeyheri 407:+
Hermannia abrotanoides 501:+; 495:+
Hermannia coccocarpa 453:+; 464:+
Hertia pallens 457:+; 437:1; 428:+
Hyparrhenia hirta 407:1; 340:+
Indigofera hololeuca 451:+; 501:+
Indigofera teixeirae 476:+; 483:+
Kalanchoe rotundifolia 300:+
Kalanchoe thyrsiflora 360:+
Lightfootia albens 407:+; 358:1; 422:+
Lightfootia nodosa 339:+
Lophiocarpus polystachyus 473:+
Lotononis clandestina 348:1
Lotononis laxa 340:r
Lotononis tenella 345:r; 425:r
Lycium cinereum 361:+
Melhania prostrata 348:+
Melianthus comosus 409:+
Melolobium candicans 500:+
Mohria caffrorum 386:+
Monsonia ovata subsp. *glauca* 434:r
Nemesia fruticans 520:+
Nestlera laxa 463:r; 464:+
Nolletia arenosa 494:+; 411:+; 354:r
Nymannia capensis 520:+; 529:+
Osteospermum leptolobum 451:+
Osteospermum scariosum 466:+; 522:+
Panicum laevifolium 457:1
Pentzia pinnatisecta 354:2a
Pentzia sphaerocephala 340:+
Phymaspermum parvifolium 451:+; 435:+; 464:1
Psammotropha mucronata 302:+; 409:1; 459:+
Pteronia mucronata 430:1
Rhus erosa 407:+
Rhus viminalis 300:r
Ruschia spec. 409:r
Salsola rabieana 447:+; 435:+; 460:+
Sarcocaulon patersonii 483:+; 399:+
Schizoglossum longifolium 403:r
Schmidtia pappophoroides 470:+; 522:+

Seddera capensis 348:1; 473:+; 481:+
Senecio radicans 528:+
Setaria lindenbergiana 361:+
Setaria verticillata 386:+; 346:+; 484:+
Stapelia jucunda 437:+
Stipagrostis anomala 451:+; 492:+
Stipagrostis uniplumis var. *uniplumis* 522:+; 500:+
Sutera atropurpurea 443:+
Sutherlandia humilis 302:+
Talinum arnotii 360:+; 411:+
Tephrosia monophylla 473:r
Tetragonia arbuscula 357:+; 436:r; 399:+
Thesium lineatum 424:+; 524:+; 481:+
Walafrida geniculata 446:2b; 376:2a; 447:r

7. INFREQUENT SPECIES OCCURRING IN THE RELEVÉS OF TABLE 13 (STIPAGROSTION)

Acacia mellifera subsp. *detinens* 521:1
Antizoma angustifolia 441:+
Aristida diffusa var. *burkei* 421:r
Asparagus racemosus 521:+
Brachiaria marlothii 526:+; 523:+
Chloris virgata 526:+
Commelina africana 440:+; 441:+
Convolvulus boedeckerianus 523:+
Cyperus usitatus 355:+
Eragrostis brizantha 525:+; 514:1
Eriocephalus spinescens 402:r; 381:r
Fingerhuthia africana 402:+; 329:r
Geigeria filifolia 355:r
Harpagophytum procumbens subsp. *procumbens* 518:+
Helichrysum arenicola 514:+
Helichrysum ericifolium 329:+
Hoodia gordonii 421:+
Lessertia pauciflora 421:r; 329:r
Limeum aethiopicum 355:+
Lycium pilifolium 523:+
Lycium cinereum 363:1
Melolobium candicans 523:+
Pelargonium fumarioides 518:r
Peliostomum leucorrhizum 438:+; 485:+
Polygala hottentotta 481:+
Pterothrix spinescens 440:+
Setaria verticillata 526:+
Solanum supinum 526:+
Sporobolus fimbriatus 421:+
Stipagrostis uniplumis var. *uniplumis* 523:+
Talinum caffrum 363:+
Tragus koelerioides 329:+; 525:+
Triraphis fleckii 485:+

TABLE 4 DIOSPYRION LYCIOIDIS

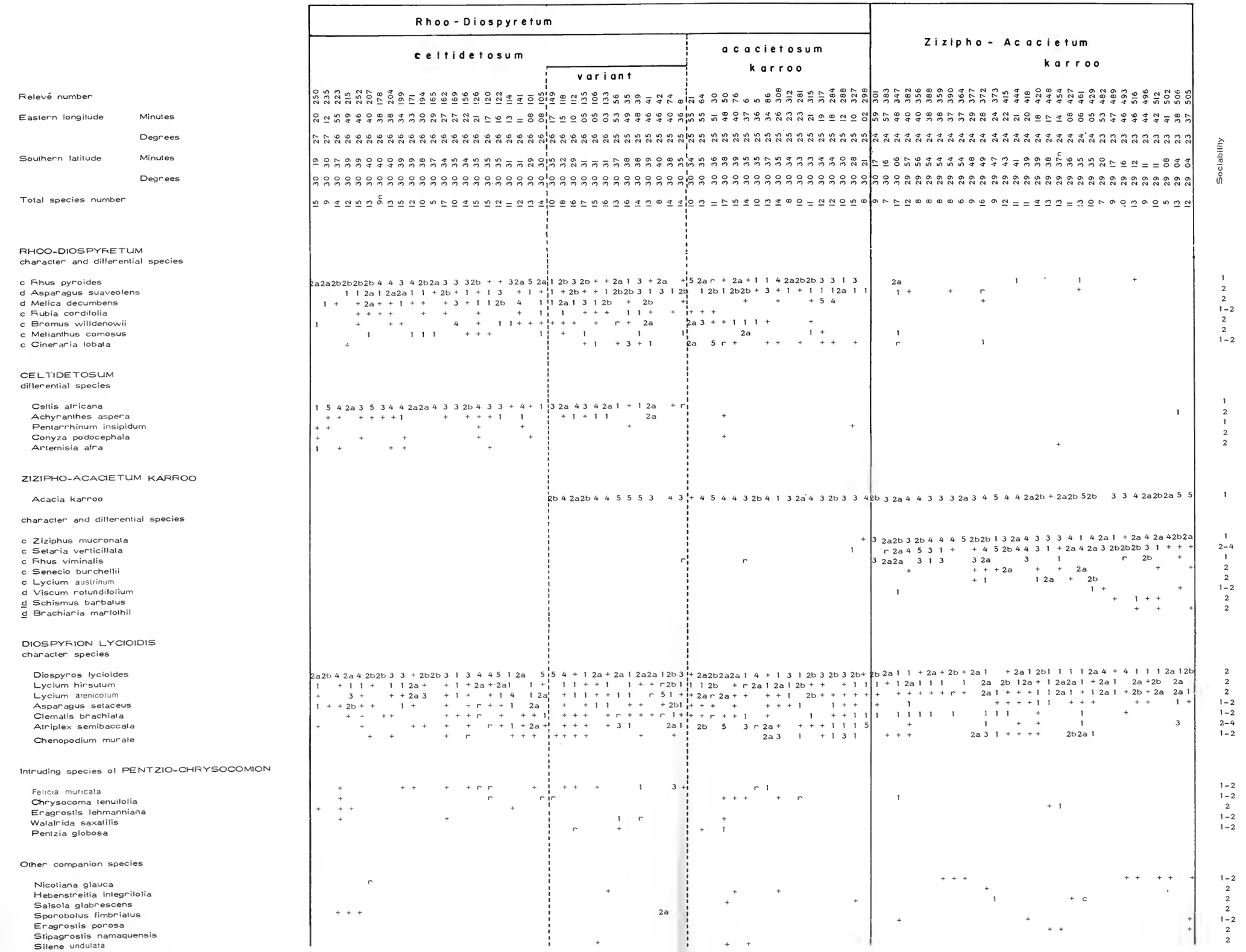

TABLE 8 EASTERN GRASSLANDS

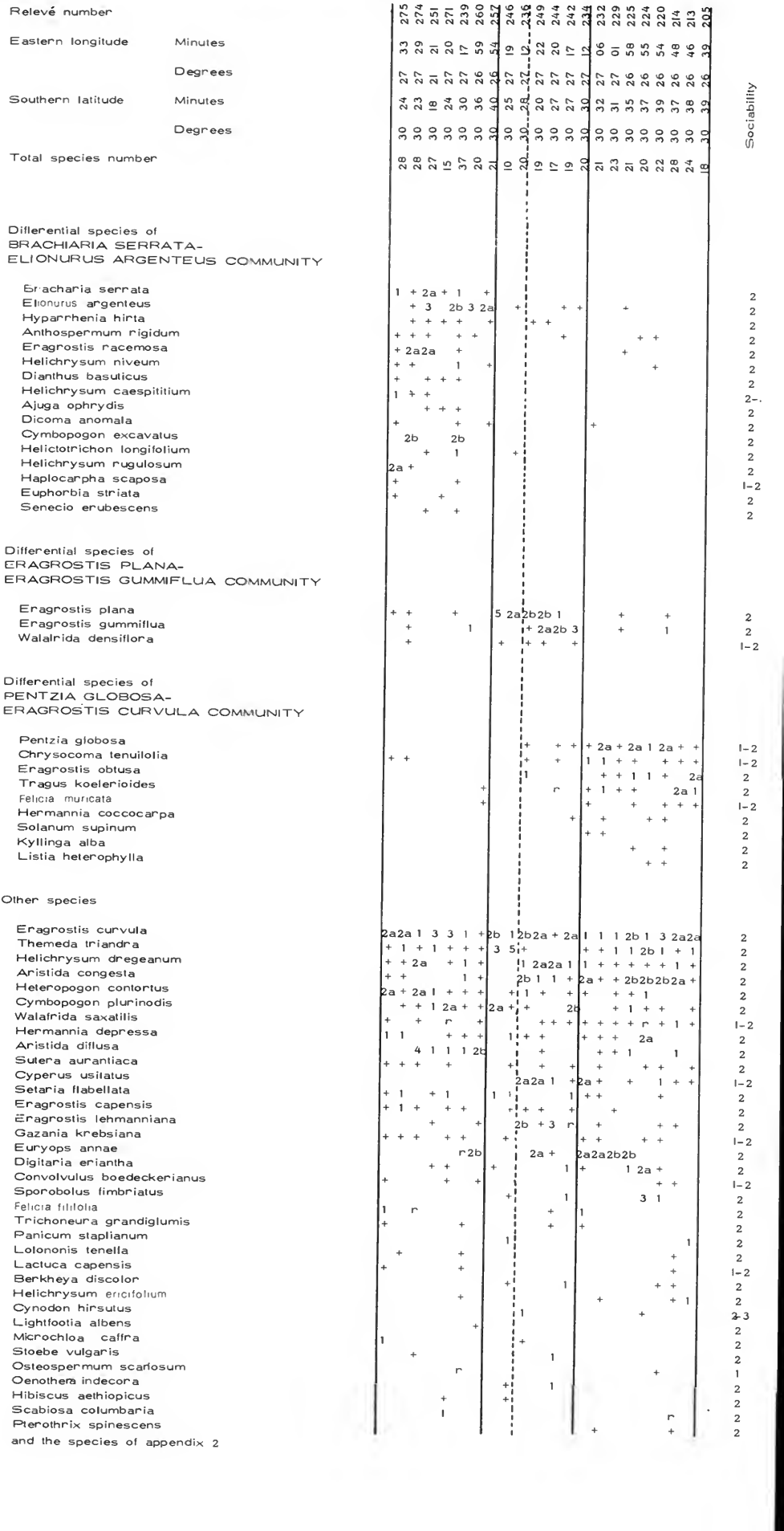

TABLE 9 HERMANNIO COCCOCARPAE - NESTLERETUM CONFERTAE

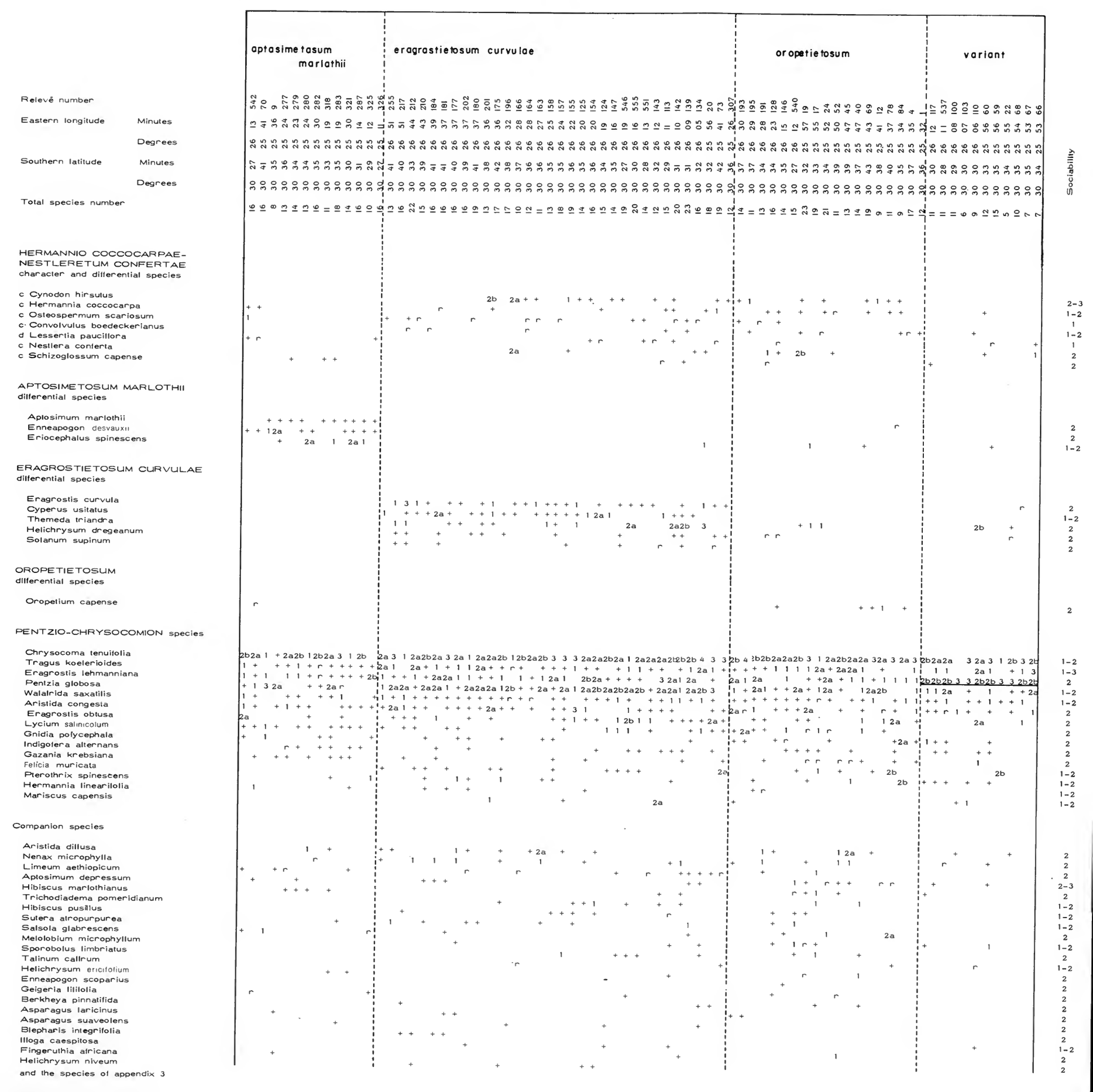

TABLE 10 GREWIO-RHOETALIA EROSAE

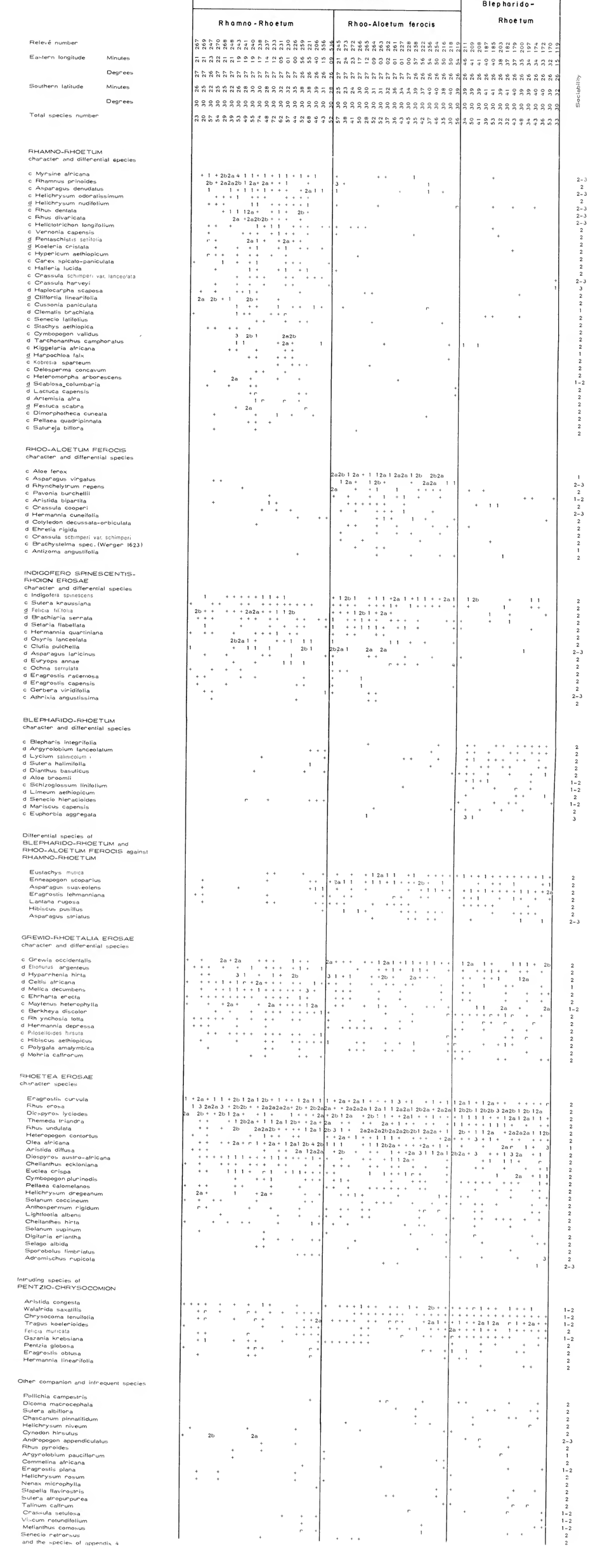

TABLE 11 — RHOETALIA CILIATO - EROSAE

Hibisco marlothiani - Rhoion erosae

Osteospermetum leptolobi — typicum

aptosimetosum marlothii

Stachyo - Rhoetum — polygaletosum

hermannietosum vestidae — variant

Nanantho vittati - Rhoetum

Mayteno polyacanthae - Oleetum africanae — typicum

chamaeretosum

Setario lindenbergianae - Buddlejetum saligna

Releve number

Eastern longitude — Minutes / Degrees

Southern latitude — Minutes / Degrees

Total species number

Specificity

OSTEOSPERMETUM LEPTOLOBI
character and differential species

c Osteospermum leptolobum
d Eriocephalus spinescens
c Pentzia sphaerocephala
c Euphorbia clavarioides
c Phymaspermum parvifolium
c Eurypos empetrifolius

APTOSIMETOSUM MARLOTHII
differential species

Aptosimum marlothii
Enneapogon desvauxii

STACHYO-RHOETUM
character and differential species

d Stachys rugosa var. linnaris
d Fingerhuthia africana
d Phyllanthus maderaspatensis
d Indigofera sessilifolia
c Heliophila suavissima

POLYGALETOSUM
differential species

Polygala ephedroides
Polygala uncinata

HERMANNIETOSUM VESTIDAE
differential species

Hermannia vestida
Polygala leptophylla
Talinum caffrum
Ehretia rigida
Rhigozum obovatum
Pachypodium succulentum
Ziziphus mucronata
Barleria rigida
Hermannia puchra
Eragrostis chloromeras
Senecio longiflorus

SALVIA NAMAENSIS - VARIANT
differential species

Salvia namaensis

NANANTHO VITTATI-RHOETUM
character and differential species

d Brachiaria serrata
c Nananthus vittatus
c Haworthia tesselata
d Dicoma macrocephala
d Hyparrhenia hirta
d Asclepias fruticosa

HIBISCO MARLOTHIANI-RHOION EROSAE
character and differential species

d Pegolettia retrofracta
c Chascanum pinnatifidum
c Hibiscus marlothianus
c Aptosimum depressum
c Mesembium microphyllum
c Helichrysum zeyheri
d Helichrysum luciliodes
c Blepharis vilosa
d Eriocephalus pinescens
c Thesium spartioides
c Trichodiadema pomeridianum
c Anacampseros lanigera

MAYTENO POLYACANTHAE-
OLEETUM AFRICANAE
character and differential species

c Maytenus polyacantha
d Asparagus laricinus
c Pelargonium aridum
d Senecio hieracioides
d Celtis africana
d Melhania calfrorum
c Crassula setulosa

CHAMAERETOSUM
differential species

Chamarea capensis

SETARIA LINDENBERGIANAE-
BUDDLEJETUM SALIGNAE
character and differential species

c Setaria lindenergiana
c Buddleja saligna
d Asparagus striatus
d Osyris lanceolata
c Solanum retroflexum
d Cussonia paniculata

RHOETALIA CILIATO - EROSAE
character and differential species

d Limeum aethiopicum
c Sutera albiflora
c Rhus ciliata
c Nenax microphylla
c Lotononis laxa
c Sutera halimifolia
c Euclea coriacea
c Aloe broomii

RHOETEA EROSAE
character species

Arrisilda diffusa
Heteropogon contortus
Rhus undulata
Themeda triandra
Eragrostis curvula
Eustachys mutica
Sporobolus fimbriatus
Cymbopogon plurinodis
Enneapogon scoparius
Diospyros austro-africana
Rhus erosa
Hibiscus pusillus
Lightfootia albens
Digitaria eriantha
Diospyros lycioides
Olea africana
Helichrysum dregeanum
Solanum supinum
Dianthus basuticus
Senago albida
Argyrolobium lanceolatum
Hermannia cuneifolia
Chellanthes hirta
Tarchonanthus camphoratus
Euclea crispa
Anthospermum rigidum
Solanum coccineum
Chellanthes ecklonlana
Agrostichus rupicola
Colyledon decussata-orbiculata
Lantana rugosa
Pellaea calomelanos
Rhynchelytrum repens

Intruding species of
PENTZIO - CHRYSOCOMION

Chrysocoma tenuifolia
Tragus koeleroides
Walafrida saxatilis
Arrisilda congesta
Pentzia globosa
Eragrostis lehmanniana
Gnidia polycephala
Lycium salinicolum
Eragrostis obtusa
Gazania krebsiana
Indigofera alternans
Pteronia spinescens
Felicia muricata
Hermannia coccocarpa
Marlieuxia capensis
Hermannia linearifolia
Convovvulus beedeckerianus
Lessertia pauciflora
Schizoglossum capense
Osteospermum scariosum

Other companion species

Asparagus suaveolens
Viscum rotundifolium
Polichila campestris
Arrisilda adscensions
Acacia karroo
Sutera atropurpurea
Felicia filifolia
Oropetium capense
Ebenarius argenteus
Blepharis integrifolia
Crassula capitella subsp. nodulosa
Geigeria filifolia
Helichrysum cneifolium
Melica decumbens
Cynodon hirsutus
Chenopodium album
Corbichonia decumbens
Helichrysum niveum
Hibiscus trionum
Pteronia glauca
Sarcela glabrescens
Cyphocarpha angustifolia
and the species of appendix 5

TABLE 12

PENTZIETEA INCANAE

Pentzio incanae - Rhigozetalia trichotomi

Enneapogono scabri - Rhigozion obovati

Zygophyllion gilfillani

Eriocephalo-Eberlanzietum

Zizipho - Rhigozetum obovati

Melhanio rehmannii - Hermannietum spinosae

Monechmatetum incani

Nestlero minutae - Pterionietum sordidae

cheilanthetosum ecklonianae

inops

typicum

pentzietosum calcareae

stipagrostietosum ciliatae

typicum

Releve number

Eastern longitude Minutes

Degrees

Southern latitude Minutes

Degrees

Total species number

Sociability

ZIZIPHO-RHIGOZETUM OBOVATI
differential species

Ziziphus mucronata
Rhus undulata
Hibiscus pusillus
Digitaria eriantha
Pollichia campestris
Argyrolobium lanceolatum
Rhus ciliata
Acacia karroo
Themeda triandra
Polygala asbestina
Viscum rotundifolium
Olea africana
Asparagus striatus
Diospyros austro-africana
Asclepias fruticosa
Hermannia cuneifolia
Stachys rugosa var. linearis

CHEILANTHETOSUM ECKLONIANAE
differential species

Sutera albiflora
Cheilanthes eckloniana
Cymbopogon plurinodis
Eustachys mutica
Hibiscus martothianus
Chascanum pinnatifidum
Melolobium microphyllum
Sutera halimifolia
Solanum coccineum
Hermannia pulchra
Aloe broomii
Anthospermum rigidum
Rhynchelytrum repens
Meriscus capensis
Pelleae calomelanos

INOPS
differential species

Tarchonanthus camphoratus
Seluga albida

MELHANIO REHMANNII-HERMANNIETUM SPINOSAE
character and differential species

c Hermannia spinosa
d Lasiocorys capensis
c Melhania rehmannii
d Acacia tortilis
d Grewia flava
c Blepharis mitrata
c Berteria lichtensteiniana
d Oropetium capense
d Eragrostis nindensis
c Mestoklema tuberosum
d Hoodia gordonii
c Hermannia desertorum
d Aloe claviflora

ENNEAPOGONO SCABRI-RHIGOZION OBOVATI
character and differential species

c Phyllanthus maderaspatensis
d Aristida diffusa
d Sporobolus fimbriatus
d Pegolettia retrofracta
c Enneapogon scaber
c Corbichonia decumbens
d Lantana rugosa
c Indigofera sessilifolia
c Rhigozum obovatum
d Enneapogon scoparius
d Heteropogon contortus
d Hermannia
d Solanum supinum
d Senecio longiflorus
d Helichrysum luciloides
c Abutilon austro-africana
d Enneapogon cenchroides
d Aplosimum depressum
c Sensevieria aethiopica

MONECHMATETUM INCANI
character species

Monechma incanum
Pentzia spinescens

NESTLERO MINUTAE PTERONIETUM SORDIDAE
character species

Nestlera minuta forme
Pteronia sordida
Eragrostis truncata
Hermannia pulverata
Aplosimum elbomarginatum
Lycium pilifolium
Microloma messonii
Euphorbia eequoris
Monechma desertorum
Monechma distichotrichum

STIPAGROSTIETOSUM CILIATAE
differential species

Lessertia peucillora
Stipagrostis ciliata
Pegonia sinaica var. minutistipula

ZYGOPHYLLION GILFILLANI
character and differential species

c Zygophyllum gilfillani
d Pentzia clecerea
d Stipagrostis obtusa

PENTZIO INCANAE-RHIGOZETALIA TRICHOTOMI
character species

Cyphocarpha engustifolia
Fingerhuthia africana
Rhigozum trichotomum
Acacia mellifera
Boscia albitrunca
Ehretia rigida
Cenchrus ciliaris
Pteronia glauca
Nestlera minuta

ERIOCEPHALO-EBERLANZIETUM
character and differential species

c Eberlanzia spinosa
d Aplosimum spinescens
d Eriocephalus spinescens
d Selsole glabrescens
d Hermannia comosa

PENTZIETEA INCANAE
character species

Enneapogon desvauxii
Barleria rigida
Pentzia incana
Limeum aethiopicum
Aplosimum lyciioides
Phaeoptilum spinosum
Plinthus karooicus
Peliostomum leucorrhizum
Thesium hystrix
Eriocephalus pubescens
Polygala hottentotte

Intruding species of PENTZIO-CHRYSOCOMON

Chrysocoma tenuifolia
Aristida congeste
Eragrostis lehmanniana
Gnidia polycephala
Tragus koelerioides
Eragrostis obtusa
Lycium salinicolum
Indigofera alternans
Felicia muricata
Gazania krebsiana
Pentzia globosa
Hermannia linearifolia
Schizoglossum capense

Other companion species

Aristida adscensionis
Dicoma macrocephala
Asparagus suaveolens
Tragus berteronianus
Eragrostis porosa
Geigeria lilifolia
Polygala leptophylla
Chenopodium album
Asparagus fericinus
Kohautia amatymbica
Commeline africana
Talinum caffrum
Cadaba aphylla
Berkheya pinnatifida
Plinthus cryptocarpus
Eragrostis superba
Gnephelium glomerulatum
Felicia burkei
Blepharis integrifolia
Psilocaulon absimile
Sarcostemma viminale
Pechypodium succulentum
Monechma divaricatum
Melhania griquensis
and the species of appendix 6

TABLE 13 STIPAGROSTION (prov.)

	329	404	402	374	381	385	355	362	363	375	421	394	442	445	456	438	440	441	525	521	485	518	514	526	527	523	517	Sociability
	Enneapog. desv.-Stipagrostietum											Pentzio calc.-Stipagrostietum																
												typicum												acacietosum erioloba				
Relevé number	329	404	402	374	381	385	355	362	363	375	421	394	442	445	456	438	440	441	525	521	485	518	514	526	527	523	517	
Eastern longitude Minutes	10	49	45	41	41	40	39	37	36	25	16	33	23	21	10	00	59	57	53	51	50	47	45	57	56	53	47	
Eastern longitude Degrees	25	24	24	24	24	24	24	24	24	24c	24	24	24	24	24	24	23	23	23	23	23	23	23	23	23	23	23	
Southern latitude Minutes	27	01	58	57	58	54c	57	55	55	46	39	50	43	40	37	33	31	30	19	15	18	15	10	19	21	16	14	
Southern latitude Degrees	30	30	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	
Total species number	13	10	10	11	8	9	20	11	16	7	20	5	17	10	9	14	12	17	13	17	14	10	15	23	20	21	17	
ENNEAPOGONO DESVAUXII STIPAGROSTIETUM character and differential species																												
d Enneapogon desvauxii	+	+	+	1	1	2a	2b	1	2a	2a	2a				+	+			+					1	r		+	2
c Nestlera laxa								1	2b																			1
PENTZIO CALCAREAE-STIPAGROSTIETUM character and differential species																												
d Pentzia calcarea				2a								2a	2a	+	+	1	1	+	1	+	r	2b	2b	+	+	2a	2a	1-2
d Aptosimum marlothii			+				+		+				+		+		1	r	+		r			+	+	+		2
d Eriocephalus pubescens				+				+						r		1	2b	1		+				2b	1			1-2
d Acacia tortilis																			+	1			r	+	1	1		1
c Nolletia arenosa								+					+						+		+		+		+		+	1
d Hermannia comosa													+										+		+			2
ACACIETOSUM ERIOLOBA differential species																												
Acacia erioloba																								1	1	1	+	1
STIPAGROSTION character species																												
Stipagrostis obtusa	3	2a	2a	1	2b	r	1	2a	2a	+	+	3	3	3	3			+	2a	2b	2b	2b	1	+	2a	2a	1	2
Stipagrostis ciliata	1	2b			3		r	2a	+		+		2a	+					2a	+		+	+	r	1	2a	2a	2
Plinthus cryptocarpus				1		r		+	+		+				+												+	2
Intruding species of PENTZIO-CHRYSOCOMION																												
Chrysocoma tenuifolia	r	+	+	r	1	2a	2a		+	1			+	1		1	2a	+		+	+	+	r	+	2a	1	+	1-2
Eragrostis lehmanniana	+			2a	1		+	+	+	+		1	2a	1	+	1	2a	1	1	1	1	+	1	+	1	1	+	2
Aristida congesta						1	3	+	2a		1					+	+	+	+	1			+	+		+		2
Lycium salinicolum							1				+		+			1	+	+						+	+	+	+	2
Gnidia polycephala	+					1	+		+				+				+						+		+	+	+	2
Indigofera alternans									+				+		+		+								+		+	2
Aristida adscensionis			1			r	+				+													+				1-2
Gazania krebsiana	+												+			+								+		+		2
Felicia muricata													+			+		+										1-2
Schizoglossum capense	+																					+					+	2
Other companion species																												
Tragus berteronianus			r	+	+	+	1			+	+	+	+		+					+		+	+	+	+	+	+	1-2
Phaeoptilum spinosum						1	+		+		+		1			1		+	1	+	+		1				+	2
Dicoma macrocephala							+		+		1		+			+	+	+		+	+	+		+	+			2
Rhigozum trichotomum		3	3					2a		4	3					4		4			4		3				1	2-5
Eragrostis porosa				+			+		+	+	+				+				1	+				1				2
Asparagus suaveolens		+	+								+		1	+							+							2
Polygala leptophylla		+			r		+																	+	+	+		2
Salsola glabrescens		r		+								r		+														2
Barleria rigida							+				+							+						+				2
Pentzia incana											+									+	+					+		1-2
Plinthus karooicus				+			+							+		+												2
Asparagus laricinus								+													+						+	2
Schmidtia pappophoroides																		+		r						+		2

and the species of appendix 7

MEMOIRS OF THE BOTANICAL SURVEY OF SOUTH AFRICA
MEMOIRS VAN DIE BOTANIESE OPNAME VAN SUID-AFRIKA

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